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MAXIMUM STRESSES IN FRAMED BRIDGES.

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III.

108. Let us now compare the weights of the three trusses examined for the most economical heights. As the diameters of the columns are unchanged, the same number of pounds of iron for castings &c., was added as before. The section of the vertical posts in the triangular truss was taken at 4.5 square inches (see art. 87).

The trusses are all of 200′ span, with 12 panels. Assumed dead load 336,000 lbs; live load 2,000 lbs. per foot, with two 60,000 lbs. weights, not less than 50′ apart, so placed as to give maximum strains in chords and web. The trusses, for the diameters of columns, strains per unit &c., given, are of the most economical heights; all of them being through bridges with leaning end posts. The following is the comparison of weights:

Truss.	Fig.	Height.	Weight in lbs.
Triangular....	7	27	324909
Whipple.....	9	29	325390
Pratt.....	5	26	333086

The comparison is thus most favorable to the Triangular, next to the Whipple, and least to the Pratt Truss, for the panel length &c., taken. Practically, the first two have the same weight.

109. An increase of the diameters of those columns that admit of it, would probably benefit the triangular most. Thus some of the interior posts of the Pratt or Whipple Trusses admit of little or no increase in diameter for a proper thickness of metal, whereas the main braces of the triangular do admit of it. With diameters of 15″ for upper chords and braces, the triangular may give the least weight; supposing the diameters of the upper chords of the other trusses to be 15″ also, the posts being enlarged where possible. On the contrary the workmanship towards the center of the space probably costs more for the triangular than for the others.

The heavy competition in this country has been productive of economy in material and workmanship, in bridge building, and the "bids" on the same design, often give the best comparisons between trusses of different types and details.

Each design has its advantages and disadvantages, and as a consequence its advocates and opposers.

A proper study of the details of trusses now before the country is then imperative.

110. It is interesting to ascertain what

inclinations of ties and braces will make the *web material* a minimum. Thus let Fig. 12 represent a panel of Fig. 11. Put AB=l, AC=l_1, BC=l_2, AD=x, DC=h; the dimensions being in inches.

w''=weight of 1 cu. in. of tie BC in lbs.

w'=weight of 1 cu. in. of post AC in lbs.

c''=cost per pound of tie in cents.

c'=cost per pound of post in cents.

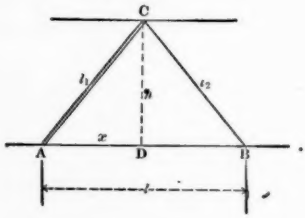
$b=7500\,(1+\theta)$=strain per sq. in. for tie.

$$b'=\frac{38500\,(1+\theta)}{4+\frac{l_1}{10d}+\frac{4cl_1^2}{r^2}+\frac{cl_1^3}{10dr^2}}=\text{safestrain}$$

per square inch for post,

as given by eq. (8), art. 53.

FIG. 12.



We find, S being the shear on the panel,

Strain on CB=$S\frac{l_2}{h}$; cost CB=$\frac{Sl}{hb}.l_2w''c''$.

Strain on CA=$S\frac{l_1}{h}$; cost CA=$\frac{Sl}{hb'}.l_1w'c'$.

Substituting for b and b' their values, we have as the total cost of tie CB and post CA,

$$\frac{S}{100\,(1+\theta)h}\left\{\frac{l^2_2w''c''}{75}+\frac{l^2_1(4+\frac{l_1}{10d}+4c\frac{l^2_1}{r^2}+\frac{cl^2_1}{10dr^2})\,w'c'}{385}\right\}.$$

Placing $l_1=\sqrt{h^2+x^2}$; $l^2_2=h^2+(l-x)^2$; differentiating with respect to x and placing the result=o, we find that for *the least cost of tie and post* (on replacing $\sqrt{h^2+x^2}$ by l_1),

$$x=\frac{308\,w''c''l}{308w''c''+30w'c'(8+\frac{3l_1}{10d}+16c\frac{l^2_1}{r^2}+\frac{c\,l^3_1}{2dr^2}}$$

Examples.—1. Let $w''c''=w'c'$, $\frac{l_1}{d}=30$, and for a hollow cylindrical post hinged at both ends $c=\frac{1}{18000}$, $r^2=\frac{d^2}{8}=\frac{l^2_1}{7200}$, whence $x=.26\,l$.

If d is given, it is evident that h has only one value corresponding to $x=.26\,l$ to be found from the equation $\frac{l_1}{d}=30=\frac{\sqrt{h^2+x^2}}{d}$. $\therefore\ h=\sqrt{(30d)^2-x^2}$.

2. Similarly we find for $\frac{l_1}{d}=20$ $x=.36l$; and for $\frac{l_1}{d}=40$, $x=.18l$.

111. If for b'' we write Rankine's formula with a constant factor of safety, 5,

$$\therefore\ b'=\tfrac{1}{5}.\frac{38500}{1+c\frac{l^2_1}{r^2}}$$

and proceed as before to deduce a formula, &c., we shall find by it that for

$$\frac{l_1}{d}=20,\ x=.36l$$
$$30,\ x=.3\ l$$
$$40,\ x=.24l$$

If in a Pratt truss (Fig. 5) of 200′ span, the *posts* as well as the ties are inclined so that $x=\frac{1}{3}l$, the web (neglecting the counter braces) weighs a few thousand pounds less than with vertical posts; the posts regarded as hinged at both ends in both cases. Using the value of b' in the previous article, for $\frac{l_1}{d}=30$ as an average, we found $x=\frac{1}{4}l$ for greatest economy. This is the value adopted in the Post truss and is, theoretically correct, for the above value of b', which is agreeable to practice as before mentioned. The *economy* of the square joint, however, due both to less workmanship as well as the use of a formula for posts with "flat ends" or "one pin ends" eliminates all saving in this direction.

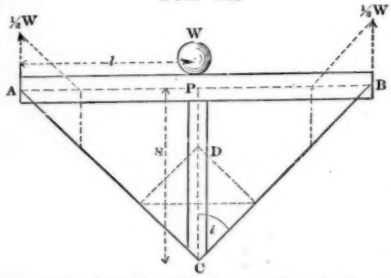
112. If the post is of wood $w'c'$ is very small compared with $w''c''$ and x is nearly equal to l. Hence in the Howe type (Fig. 6) the braces should be of wood—never of iron—for economy. Similarly, if the post AC is of cast iron, x ap-

proaches $\frac{1}{2}\,l$ as its proper theoretical value. The chords will influence the above results very slightly for usual diameters of upper chord.

113. For deck bridges and the triangular through truss, the shear on the post is greater than on the tie, and the post should be more nearly vertical. This supposition is easily included in the formula.

114. *Most Economical Depth for a Fink Element.*—Let a weight W act at P, Fig. 13. Call the constant length, BP=AP=l; the variable height of post PC=x; the strain per square inch on ties AC, BC, = T, on chord AB=b', on post PC=b. The weight W is directly supported by the post PC.

FIG. 13.



Decomposing W=DC at C, the strain on AC or BC is $\frac{1}{2}$W *sec.* $i=\frac{\mathrm{W}}{2}\cdot\frac{\sqrt{x^2+l^2}}{x}$.

This strain is in equilibrium at A or B with the reaction $\frac{1}{2}$W and the chord resistance $\frac{1}{2}$W *tan* $i=\frac{\mathrm{W}}{2}\,\frac{l}{x}$.

On dividing the strain on each member by its strain per square inch and multiplying by the length of the member in inches, we get its volume. Thus the total volume of AC+BC+PC+AB is

$$\mathrm{W}\left(\frac{x^2+l^2}{\mathrm{T}x}+\frac{x}{b}+\frac{l^2}{xb'}\right),\ \textit{to be a min.}$$

Now T is constant; also b', since l is constant, but b varies with x.

115. *Regarding b as constant;* on differentiating, &c., we readily find, *for a min. vol.*

$$\frac{l^2}{x^2}\left(\frac{1}{\mathrm{T}}-\frac{1}{b'}\right)=\frac{1}{\mathrm{T}}+\frac{1}{b}$$

$$\therefore\ tan.\ i=\frac{l}{x}=\sqrt{\frac{(b+\mathrm{T})\,b'}{(b'+\mathrm{T})\,b}}$$

Thus let T=b'=10000,

b=10000, i=45°
b= 7000, i=47°47′
b= 6000, i=49° 3′
b= 5000, i=50°47′
b= 4000, i=52°55′, &c.

116. Regarding $b=\dfrac{38500(1+\theta)}{\left(4+\frac{1}{10}\frac{x}{d}\right)\left(1+c\frac{x^3}{r^3}\right)}$

as variable we find,

$$\tan.\ i=\frac{l}{x}=\sqrt{\frac{b'\mathrm{T}}{b'+\mathrm{T}}\left\{\frac{4+\frac{x}{5d}+\frac{12cx^2}{r^2}+\frac{4}{10}\frac{cx^3}{dr^3}}{38500(1+\theta)}+\frac{1}{\mathrm{T}}\right\}}$$

For a given $\frac{x}{d}$ we can of course find *tan.* i; but generally d is given and we can not know $\frac{x}{d}$ until x is found. Hence, given d, we cannot determine *tan* i, except by a series of approximations.

But as in the case of beam trusses, having assumed x and d, unless the preceding equality holds, the most economical depth has not been chosen, and the formula will indicate whether x is too small or the reverse.

Examples.—Let, b' = T = 10000, and let PC be a hollow cylindrical column $\therefore \frac{x^2}{r^2}=\frac{8x^2}{d^2}$; $\frac{x^3}{dr^3}=\frac{8x^3}{d^3}$. Also place $c=\frac{1}{24000}$ and $\theta=\frac{1}{3}$.

Then for,

$\frac{x}{d}$ =20, *tan.* i=1.237 ∴ i=51° 3′

$\frac{x}{d}$ =30, *tan.* i=1.473 ∴ i=55°50′

$\frac{x}{d}$ =40, *tan.* i=1.761 ∴ i=60°25′

Thus somewhat shorter posts are required than when b is taken constant.

117. Let us now investigate a *Fink truss* (deck bridge) Fig. 14 for maximum strains and minimum material. Assume as before a 200′ span, but divide it into 16 panels of 12½′ each. As before, let the weight of bridge=336000 lbs., or 10500 lbs. per panel on one truss; the car load, uniformly distributed, 1000 lbs.

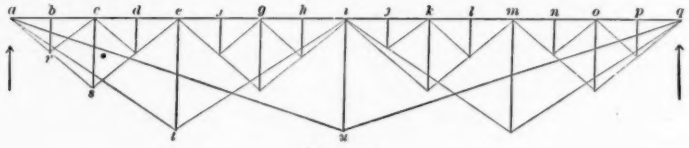


FIG. 14.

per foot or 12500 per panel for one truss, and the locomotive excess, two weights, 30000 pounds each for one truss and 50′ apart, to be so placed as to give maximum strains on chords, posts or chain system.

Each 30,000 pounds rests on 3 drivers for one truss, 6′ apart or a total wheel base of 12′ ∴ there is 10,000 pounds on each driver. *Hence when the center driver is at any post as c, the adjoining posts bear* $\frac{6}{12.5}$ 10,000=4800 *lbs., and the post c therefore* 30,000−9600=20400 *directly.*

118. If a weight is placed anywhere on $\overline{ac}$, since the element *arc* acts independently, *the reactions at a* and *c are determined by the law of the lever.* Similarly for the systems *ase, ati,* and *auq;* for the posts at the end of the system act as abutments to the system considered, and the reactions can only be determined by the simple law of the lever, irrespective of the pattern of the chain system used.

119. It follows, therefore, that the max. strains on posts *b, d, f* . . . . =1 panel dead and car load, (23000) + 20400 of loc. excess (center driver bearing on post)=43400 pounds.

The dead load is really less as the chains, *as, au* . . . only rest on *cs, ct* . . . ordinarily, but the section of the post would hardly be taken less than this strain gives, owing to oscillation of engine sometimes increasing the reaction at *b, d* . . . due to engine weight. But for posts *b* . . . put $\theta=\frac{5000}{43400}=.13$.

Next, let center driver bear at *c*.

The post *c* bears directly 23000 lbs. car and dead load+20400 loc. excess; also 23000+4800 transferred from *b* and *d*, making in all 71200 ∴ $\theta=\frac{21000}{71200}=.3$.

The post *e*, bears directly 43400+$\frac{1}{2}$ car and dead load at *b, c, d* and *f, g, h,* (69000)+(2.$\frac{3}{4}$.4800+$\frac{1}{4}$.4800) loc. weights borne at *d, f* and *h*=120800 lbs. *if* center driver is at *e*; but with locomotives at *c* and *g*, post *e* sustains $\frac{1}{2}$ load on *a i*= 122000 lbs. which is therefore its max. strain; and $\theta=\frac{4^2}{12^2}=.34$.

If locomotives are supposed at *d* and *h*, the reaction at *e* due to them is ($\frac{3}{4}+\frac{1}{4}$) 30000=30000 as in the preceding case.

Lastly to find the max. strain borne by post *i*. It bears 8 panels, car and dead load (184000 lbs). With engines at *g* and *k*, by art. 118, post *i* bears $\frac{3}{4}$60000 loc. load. With engines at *h* and *l*, *i* sustains $\frac{7}{8}$30000+$\frac{5}{8}$30000=$\frac{3}{4}$30000 as before; but with engines at *i* and *m*, *i* sustains $\frac{1}{8}$30000+2$\frac{3}{4}$4800+20400=43800 or less than the 45000 before.

120. From the above we see that when one locomotive only can get on the system, it must be placed over the central post of that system to find its max. strains; when two locomotives can bear on one system they must be placed either side of the central post.

The above strains are entered in the following table. The max. strains on the ties at the foot of the posts are found by multiplying $\frac{1}{2}$ the max. strains on posts by *sec. i*, *i* being the inclination of the tie to the vertical.

The lengths and diameters of posts are assumed as in the table.

It was not considered judicious to make the center post *i* longer than 30 diameters, though for theoretical economy it should be much longer.

121. *Chord Strains.*—As in art. 114, to find the chord strain due to any element we multiply $\frac{1}{2}$ weight at foot of post by *tan. i.*

Thus for the uniformly distributed car and dead load of 23000 lbs. per panel, post *b* bears 23000 lbs; post *c*, 46000; post *e*, 92000 and post *i*, 184000 lbs. Similarly for similar posts so that the strain on *a q*, for uniform load is the same throughout and equals

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″				□″	′			lbs.	
Post b.....	6	20	$\frac{5}{16}$	43400	.13	6400	6.8	10	16	$\frac{10}{8}$	3627	
c.....	11	22	$\frac{5}{16}$	71200	.30	6950	10.3	20	8	"	5493	
e.....	$13\frac{1}{6}$	30	$\frac{1}{2}$	122000	.34	5670	21.5	$\frac{10}{2}0$	4	"	9555	
i.....	$13\frac{1}{3}$	30	1	229000	.37	5800	39.5	$\frac{10}{3}0$	2	"	8778	27453
Tie ar.....				34720	.13	8470	4.1	16	32	"	6997	
as.....				56960	.30	9750	5.8	32	16	"	9898	
at.....				109983	.34	10050	10.9	60.1	8	"	17469	
au.....				362049	.37	10420	34.7	105.4	4	"	48765	83129
Chord aq.....	$13\frac{1}{3}$	11.3	$1\frac{3}{16}$	485625	.39	10140	47.9	200	2	"	63867	63867

$\frac{1}{2}(184000\times 3+92000\times 1\frac{1}{2}+46000\times\frac{8}{20}+23000\times 1\frac{1}{4})=388125$ lbs.

122. Next consider the locomotive excesses, 50′ apart, consisting of 30000 lbs. each on 3 drivers. With center drivers at g and k, these posts support directly and indirectly 25200, the adjacent posts 4800 lbs each (art. 117); e and m, will bear 15000, and i 45000 lbs. applying the simple law of the lever to determine these reactions. This gives as the total strain on the parts $\overline{ei}$ or $\overline{im}$, due to loc. excess

$\frac{1}{2}(45000\times 3+15000\times 1\frac{1}{2}+25200\frac{8}{20}+4800\frac{8}{20})=97500$ lbs.

Similarly, for engines at e and i, the part $\overline{ei}$ experiences a strain of 92400 lbs. which differs but little from the preceding; hence I have regarded the chord $\overline{aq}$ as strained throughout by $97500+388125=485625$ lbs. as entered in the table.

With engines at c and g, the chord strain on $\overline{ai}$ due to loc. excess is 86250 lbs.—less than in preceding cases.

123. The trusses were assumed 14′ from center to center; floor beams being 15.5′ long and 24″ deep; the web, $\frac{1}{2}$″ thick. The loss in the rivet holes is assumed equal in effect to the resistance afforded by the web &c. The floor beam max. live load is 63880 lbs. (see art. 15), to which add 6738 lbs. dead load. The moment at center is thus, $35309\times 54''=fda=7500\times 24\times 10.6$. The section of a floor beam is thus, 28.5 sq. in. and its weight 1472 lbs. Similarly the stringers of wood, each 16″×6.6 (see Fig. 9) or of iron **I** beams, 16″ deep, weigh about 213 lbs. per foot. The transverse bracing was put at 11400 lbs. as for the Whipple truss, the rails and cross ties as before. The "Whipple" deck truss, (art. 91) with which this one will be compared was subjected to as near the same conditions as possible, except that the panel length of the former was taken at $16\frac{2}{3}$ feet, whereas a different panel length might be more economical. The same percentages for castings, bolts, &c., was added to both.

The following is the

BILL OF MATERIALS.

Fink Deck Bridge, 200′ span, 16′ pancls.

	lbs.
Ties	83129
15 p. c.	12469
Chord and posts	91320
20 p. c.	18264
Lateral tie rods and struts	11400
17 Floor beams, 24″ deep	25000
Wooden stingers	42600
Rails, cross ties, &c.	33200
Total weight of bridge	317382
Assumed weight	336000
Assumed weight too great by	18,618

124. Let us now ascertain if each element of the truss has its most economical depth.

For the element arc, we must substitute in the value of $tan.\ i$ (art. 116), T=8500, $b'=10200$, $\frac{x}{d}=20$ and $\theta=.13$, as found from the table; whence we find that for the most economical depth $\frac{l}{x}=1.3$ $\therefore$ for $l=12.5$, $x=\overline{br}=9.6$ feet, As we assumed $\overline{br}=10$, the result is almost exact; in fact considering the thickness of chord, it is practically exact.

Similarly for the element ase: T=9800, $b'=10200$, $\theta=.3$, $\frac{x}{d}=22$ whence tan

$i=\frac{l}{x}=\frac{4}{3}$ ∴ for $l=25$, $x=\overline{cs}=18.8$ feet.

This value differs only 1.2 feet from the 20 feet assumed, or really only .6 foot say, considering the thickness of chord. The depth is very slightly too great.

For the element *ati*, T=10050 $b'=10140$, $\frac{x}{d}=30$ and $\theta=.34$, whence (see 2nd example, art. 116) $\frac{l}{x}=1.473$ ∴ for $l=50$, $x=et=33.9$, we assumed 33.3. Practically then, the most economical depths have been chosen for all the elements excepting *auq*, which is necessarily circumscribed in depth.

125. *The formula of art.* 98 applies directly to a Fink element, Fig. 13, since the chord strain varies directly as *tan. i* or *as the depth*, and the shearing force, $\frac{1}{2}$ W, is the same on the ties of Fig. 13 for any depth; these being the only requirements of the formula.

For a Fink element, Fig. 13, formula (14), art. 98, takes now the following shape,

$$W_c=W_t \cos. 2i+W_p(1+m);$$

in which

W_c=Weight of chord A B

W_t=Weight of ties AC+CB.

and

W_p=Weight of post PC.

In the value of m, for hollow cylindrical posts, hinged at one end,

$$c\frac{l^2}{r^2}=\frac{1}{3000}\left(\frac{l}{d}\right)^2.$$

Now for the element *ati* Fig. 14, $i=56\ 19'$, *cos.* $2i=-.385$.

From the table art. 120 we get 4 W_t=17469, 4 W_p=9555; and computing W_c we find 4 $W_c=(61000\times 6\div 10140)\ 10\frac{9}{3}=12030$. Also for $\frac{x}{d}=30$, $m=\frac{3}{4}+\frac{18}{35}$; whence

$$4\ W_c=12030>17469\times -.385+9555\left(1+\tfrac{3}{4}+\tfrac{18}{35}\right)=11235$$

The chord weight is very slightly too great, which indicates that the depth is too small for the most perfect economy; the same conclusion previously arrived at.

On comparing now the weight of the Fink with that of the Whipple deck bridge, (*art.* 91), *we see that the Fink is lighter by* 10,072 *lbs.*

126. *Fink Through Bridge.*—If we draw a line *tu* (Fig. 14) parallel to chord and drop "suspenders" from the foot of posts, as *r*, *s*, . . . to hold up the roadway *tu*, and also add vertical posts at *a* and *q*, the depth of the truss, we have an outline drawing of the Fink through bridge. Call the points of the roadway vertically under *a*, *b*, *c*, ... respectively *a'*, *b'*, *c'* . . . .; and consider the element *arc* conjointly with the suspender *rb'* for economy. Call $br=x$, $bb'=h$ ∴ $rb'=(h-x)$. As the post *br* only supports one panel upper chord, &c., its section will practically be taken much larger than the 2500 pounds about of dead load requires. Hence we can regard its section=S *constant* as *br* varies in length.

As in art. 114, call the strain per square inch on ties (*ar*, *rc*, *rb'*), T; on chord, *b'*. Then we have as in art. 114 the total volume of *ar*, *rc*, *b'r*, *ac* and *br* (calling W=load on suspender *b'r*),

$$W\left(\frac{x^2+l^2}{Tx}+\frac{h-x}{T}+\frac{l^2}{xb'}\right)+Sx=a\ min.$$

whence,

$$\frac{l}{x}=\frac{bc}{br}=\sqrt{\frac{b''TS}{W(b'+T)}}$$

Now putting S=4.5, $b'=10000$, T=8500, W=43400, it follows that for economy that $x=l\div.685$. Thus if $l=12.5$, $x=br=18$. For S=10, $x=12.5$ feet, &c. The first values (nearly) are taken from the following table, and the results are thus correct for the element *arc*: but in the element *ase*, the cross section of *cs* must not be assumed constant for different depths. If it were, then it follows that for $b'=10{,}000$, T=9700, W=71200 and S=8 that $l=\frac{3}{4}x$ ∴ $x=33.3$ feet=*cs*. For S=14 (about), $x=l$.

It is easy to deduce a formula regarding *b* for the post *sc* as varying, but it is perhaps simpler to determine the proper value for *sc* by trial. From the formula above we see that as S diminishes, that the angle between the ties becomes less.

127. Let us assume as before that the ties *ar* and *as* are equally inclined, but place their inclination now at 45°, the depth of truss, no. panels, &c., being assumed as before.

The maximum strains on ties and top chord are determined as before, since they depend only upon the load borne at the foot of each post, whether that load is communicated by posts or suspenders or both.

The chord strain due to uniform car and dead load

$=\frac{1}{2}(184000\times 3+92000\times 1\frac{1}{2}+46000+23000)=379500;$

and that due to loc. excess placed at g' and k'

$=\frac{1}{2}(45000\times 3+15000\times 1\frac{1}{2}+30000)=93750$

The sum of the two is entered in the following table. With engine at b', post c bears about 41000 pounds. The posts e and i bear, one panel of car load (12500) + one panel roadway (3535), or 16035 pounds *less than before*, giving the max. loads ever borne by

Post e, $122000-16035=105965$
" i, $229000-16035=212965$

The dead loads carried by these posts are 17465, 38465 and 80465 so that θ has the respective values, 42, 36, 37.

The suspenders bear 32900 lbs. live load ($=20400+12500$) and 3100 lbs. roadway: in all 36000 lbs.

Piece.	d	$\frac{l}{d}$	th	Strain.	θ.	b	Area.	Length.	No.	k.	Weight.	Totals.
	″		″				□″	′			lbs.	
Chord.....	$13\frac{1}{8}$	11.3	$1\frac{3}{16}$	473250	.39	10140	46.7	200	2	$\frac{1}{8}$	62267	62267
Post *br*.....	5		$\frac{1}{4}$	2500	1.		3.6	12.5	16	"	2400	
cs.....	$7\frac{3}{8}$	37	$\frac{9}{16}$	41000	.42	4880	8.4	25	8	"	5600	
et.....	$13\frac{1}{8}$	30	$\frac{1}{2}$	105965	.36	5750	18.4	$1\frac{0}{8}$	4	"	8180	
iu.....	$13\frac{1}{8}$	30	$\frac{11}{16}$	212965	.37	5800	35.5	$1\frac{0}{8}$	2	"	7889	24069
Suspenders..				36000	.13	8470	4.3	20.8	16	"	4770	
" ..				36000	.13	8470	4 3	8.3	8	"	952	5722
Tie *ar*.....	$\frac{43400}{2}\cdot\frac{35.4}{25}=$			30727	.13	8470	3.6	17.7	32	"	6797	
as.....	$\frac{71200}{2}\cdot\frac{35.4}{35}=$			50410	.3	9750	5.2	35.4	16	"	9818	
at.....	$\frac{122000}{2}\cdot\frac{60.1}{33.3}=$			109983	.34	10050	10.9	60 1	8	"	17469	
au.....	$\frac{229000}{2}\cdot\frac{105.4}{33.3}=$			362049	.37	10420	34.7	105.4	4	"	48765	82849

128. With trusses 16′ apart, center to center, the iron floor beams, 26″ deep are estimated to weigh 1866 lbs. weight per panel; stringers and track as before 4738 lbs. We now form the following:

BILL OF MATERIALS.

Fink through bridge, 200′ span, 16 panels, 33′.3 deep.

	lbs.
Chain system and suspenders.....	88571
15 p. c. for bolts, nuts, eyes and pins	13286
Chord and posts	86336
20 p. c. for castings	17267
Floor beam loops.....	5000
Lateral rods, struts and portals. ...	15000
15 floor beams (26″ deep).....	27990
Stringers (of wood).....	42600
Rails, cross ties, &c.....	33200
Total weight.....	329250
Assumed weight	336000

The lateral struts and portals were increased over previous trusses examined by 4600 lbs. on account of the greater depth of this truss. The roadway for greater stability, should be formed of closely spaced cross bearers, extending from truss to truss, but we have *estimated* as above. If we subtract the weight of portals, say 5000 lbs. we get the weight of bridge for calculation 324,250 lbs.

The four-end posts or "pier towers," are 33.3 feet high and for 30 diameters weigh in all 17111 lbs. since they sustain a max. load of 226500, when train extends from farthest abutment to nearest panel. These pier towers should be given a broader base for equal stability with other trusses, and hence should weigh more than the above. Putting them at 17111 the total weight of bridge and towers is 346,361 lbs. which is more

than for the Pratt, Whipple or Triangular, previously examined.

129. To ascertain if the most economical depth has been chosen, let us keep the inclination of the ties, inclined 45,° at that angle. Then for a change of height $\triangle h$, only the suspenders, end posts and weights, due to systems *auq* and *ati*, need be examined. Call w_s = weight of suspenders of height $rb' = 20.8 = h_1$ then if the height of the truss h = 33.3 is increased by $\triangle h$, *the new weight of suspenders* is

$$w_s \frac{h_1 + \triangle h}{h_1} = w_s + w_s \frac{\triangle h}{h_1}$$

Similarly the new weight of the other suspenders whose height $= h_2 = 8.3$ is

$$w_s' + w_s' \frac{\triangle h}{h_2}$$

If these expressions are added to the value of $F(h + \triangle h)$ in art. 98, and the subsequent reductions made as in that article, (the transformations the above terms undergo are very easily traced), we find in place of *eq.* (14) that for the most economical height,

$$W_c = w_s \frac{h}{h_1} + w_s' \frac{h}{h_2} + \Sigma w(\cos.\ 2i + \frac{h^2}{l^2} m)$$

130. In this formula w_c = weight of chord due to variable elements *ati* and *auq* = 55733 lbs. The posts *et*, *ia* and end posts being all 30 diameters long and vertical, cos. $2i = 1$, $\frac{h^2}{l^2} = 1$, $m = \frac{3}{4} + \frac{1}{3}\frac{8}{5}$, and their weight $W_p = 16069 + 17111 = 33180$ lbs.

The weight of ties, *at*, *ti*, . . . , inclined at 56°19 to the vertical is $w_t = 17469$. For them *cos.* $2i = -.385$. The w't. of *au uq* $= w_t' = 48765$. For them *cos.* $2i = -.6$. Also $w_s = 4770$ and $w_s' = 952$.

Now if the most economical height has been chosen we should have

$$W_c = w_s \frac{h}{h_1} + w_s' \frac{h}{h_2} + W_t \times (-.385) + W_t'(-.6) + W_p\,(1+m).$$

Actually we have,

$$W_c = 55732 > 11250 - 35985 + 62714 = 37979,$$

The chords being the greater, the depth ($33\frac{1}{3}'$) is too small for theoretical economy; but it would hardly be prudent to increase it.

131. If however we take the pier towers at 27000, the right member equals 57096, which nearly equals W_c.

132. The Fink truss is better adapted for a deck than a through bridge, and possesses one advantage for either form over all others; "compensation" under live loads or changes of temperature; each isosceles triangle or "element" being independent in its action of every other, there can be no loose counters causing distortion of the bridge as in some beam trusses. Its action in practice is said to be "perfect." It would seem that an increase of diameter of the heavy chord of the Fink would benefit it more than a similar operation would benefit the quadrangular trusses. A re-estimate can alone determine.

132. It may be remarked that the number of panels in a Fink is, from the peculiar design, some power of 2; 2, 4, 8, 16, 32, &c., thus fixing a panel's length. The Quadrangular trusses on the contrary can have any number of panels, thus giving it a greater adaptability to various spans. The Triangular truss with suspenders has necessarily an even number of panels. But with some of the center panels built on the quadrangular plan (as has been done), thus giving short posts, where material is most likely to be wasted, the adaptability to any span can be made equal to that of the quadrangular trusses.

For very long and deep spans—300 to 600 feet and upwards—vertical posts throughout would seem to be desirable; for if inclined, the flexure from their own weight would be appreciable and might continually increase besides.

The posts, when the truss is high enough to admit of it, are often braced together between their ends, thus shortening practically their length as compared with their diameters, and adding materially to the stiffness of the system.

133. *Bow String Girder.*—This truss, depicted in Fig. 15, is assumed, as before, to have 200 feet span, divided into 12 panels, and to weigh 336000 lbs. (entire bridge). The center height is assumed at 30 feet. The counters are omitted in Fig. 15, as we shall assume them out of action when the bridge is loaded uniformly, which case will first be investigated.

134. Using Bow's ("Economics of

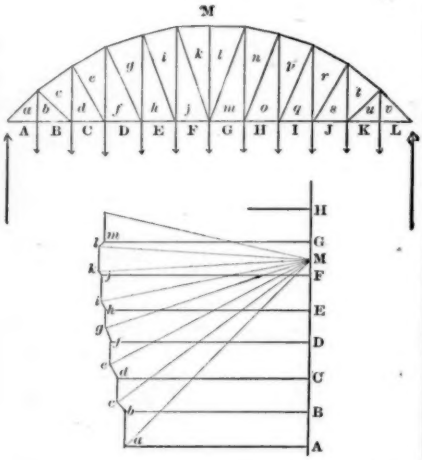
Construction," &c.), notation, we denote any bridge member, in Fig. 15, (1) by the two letters placed either side of it; thus the first vertical on the left is *ab*, the next *cd*, &c. Similarly the first bow piece on the left is *a*M, the next *c*M, &c.; the first chord piece is *a*A, the next *b*B, &c. The same notation applies to the forces AM, AB, BC, &c.

135. Let the bridge be loaded with its own weight only, 14000 lbs. per panel on one truss; *i.e.*, AB=BC=CD=&c.= 14000 lbs. Then the reactions AM and LM are $5\frac{1}{2}\times 14000$.

Lay off, in Fig. 15 (2) the forces AB, BC, &c. vertically, also the reaction AM, and draw the lines, as per figure, whose extremities are marked by any two letters, *parallel* to the members of the truss, Fig. 15 (1), indicated by the same letters; then will the lengths of the lines in (2), measured to the same scale as the forces AB, ... give the strains on the members of the truss (1) indicated by the same letters.

FIG. 15.

(1)



(2)

Thus M*a*, (2), is drawn parallel to M*a*, (1), and M*a*, (2), measured to scale is the strain on M*a* (1).

Similarly A*a*, *ab*, *bc*, Mc, &c., in (2) are the strains on the corresponding parts in (1).

136. This results from the well-known law of mechanics, that if a number of forces acting at a point are in equilibrium, then if we lay off the forces in order, "the polygon should close." Also, having given, at any apex, the direction of one force, by following around the corresponding polygon we find the directions of the others. If the force, representing the stress on a member, is thus found to *act away from the apex.*, the member is in tension, *if towards the apex* the member is in compression.

Thus at apex AM*a*, AM is given acting upwards: then in (2) following around the polygon AM*a*A in order, M*a* is found to act *towards*, and *a*A from the apex; *i.e.*, *a*M, (1), is in compression and *a*A, (1) in tension.

Be careful to note now that these same pieces *act* in an opposite direction at their other ends. Thus at apex AB*ab* (1), *a*A acts to the left, *being in tension;* then following around the corresponding force polygon (2) in the order A*ab*BA, we find *ab* and *b*B acting away from the apex, hence in tension. Next at apex M*abc* (1), *a*M*cba* (2) gives CM compression and *bc* tension. Similarly all the web members will be found in tension, the bow in compression and the chord in tension.

We determine first the strains at a chord apex, to find the strain on the vertical, then go to the bow apex above it, where, the strains in *two pieces* only being unknown, can be readily found.

137. The strains were of course determined from a larger drawing, the truss being drawn to a scale of 10 feet= 1 inch, and the force diagram being drawn to a scale of 20000 lbs.=1 inch.

We thus find that the *dead load alone* strains the ties, *bc*, *de*, *fg*, *hi*, *jk*, 4700, 4000, 3300, 2900 and 1300 pounds respectively. The verticals thus carry the greater part of the weights. With engine at the foot of tie *ab*, its maximum strain is 45000 lbs.

It was not considered judicious to proportion the verticals (when acting as ties) for a less strain, as a very slight error in the length of a diagonal could cause the vertical (neglecting the counter, supposed loose however) to sustain the whole panel reaction of 45000 lbs.

138. For a uniform live load, the force diagram is similar to (2), and the bow and chord strains can be most conveniently obtained from it. With the locomotive excess placed so as to give

max. chord strains, a new diagram would be required for every new position of the load however and on that account it is simplest to use the principle of moments.

139. The maximum moment about an apex n panels distant from the abutment is given by the eq., art. 39, by simply dividing by h, as is sufficiently evident.

$$\therefore\ M_n = \left\{ \frac{Pl}{2}(N-n) + \frac{El}{N}\left(N - \frac{c}{l} - n\right) \right\} n$$

In the case of the Bow String girder, the lever arms for panels Aa, Cd, Df, Eh, Fj respectively are ab, cd, ef, gh and ij respectively. The lever arms for the arch panels Ma, Mc, Me, Mg . . . are the perpendiculars drawn from the apices Ab, Bd, Cf, ... respectively to the chords of the arcs Ma, Mc . . . .

Substituting now in the last eq.,

$N=12$, $l=\frac{5}{3}^0$, $E=60000$, $\frac{c}{l}=1\frac{1}{2}$, $P=30666$

we have,

$$M_n = [255550(12-n) + 83333(10\tfrac{1}{2}-n]n$$

whence we find the strains in,

$$Aa = Bb = \frac{M_1}{9.8} = \frac{3602713}{9.8} = 367620,$$

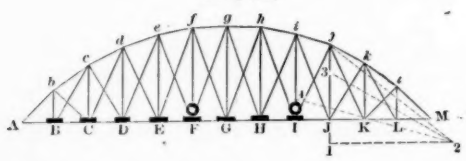
$$Ma = \frac{M_1}{8.43} = 427000,$$

$$Cd = \frac{M_2}{17.3} = \frac{6527660}{17.3} = 377320,$$

&c., &c., as entered in the table below.

140. *Maximum Web Strains.* The following method of ascertaining the max. web strains is due to Stoney ("Strains in Girders," etc., art. 211). Suppose the truss without weight. Let the live load, engines in front, extend to the foot of the tie whose max. strain is required. Then, in Fig. 16, if we suppose the panel IJ ij cut and forces applied at the cut pieces equal and opposite

FIG. 16.



to the resistances of those pieces the right segment of the truss will be held in equilibrium by the reaction at the right abutment, the horizontal tension in IJ, and the resultant of the strains in Ij and ij. The two former met at M, hence the resultant at j must pass through M.

Therefore, if we draw, by scale, $\overline{ji}$ vertically, and equal to the reaction (which is also the shear over panel IJ), and draw 12 horizontally till it meets jM produced at 2, then $\overline{2j}$ is equal and opposed to the forces supposed *applied* in the directions, ij and $j1$ at j; whence drawing 24 parallel to $\overline{ij}$, $j4$=strain on tie, and 24 on bow ij for this position of the load.

Similarly if we suppose the truss severed through IJjk, 2j will be the resultant of the resistances of jJ and jk at j; or, $j2$ acting in the direction from j to 2 is in equilibrium with those resistances. Hence, drawing 23 parallel to jk, on following around the force polygon in the order, $j23j$, we find $3j$=strain on jJ *compression* as it acts *towards* j.

141. From this method of construction we see that the strains on any two web members as Ij and jJ are greater the greater the reaction, provided there is no load on the right segment; hence, omitting the case of the right segment being loaded for the present, the strains on a tie and the vertical connecting with its top, when the greater segment only is loaded are a maximum, when the live load—engines in front—extends from the *farthest abutment* to the foot of the tie. The counters Ji and Kj are supposed loose or out of action, hence were disregarded.

141. We proceed similarly for the other diagonals and verticals. The method is the same for the counters Fg, Ef, ... : the live load extending from their feet to the nearest abutment for their max. strains. Now add, with its proper sign (+ for compression, — for

tension), the effect on the *posts* of the dead load, as found from the construction Fig. 15, to the strains just found, from Fig. 16, *when the live load extends to the farthest abutment.*

Post Fig. 16.	Dead Load.	Live Load.	Total Strain.
K*k*	− 11800	+ 13000	+ 1200
J*j*	− 11000	+ 22000	+ 11000
I*i*	− 11200	+ 27500	+ 16300
H*h*	− 11900	+ 31000	+ 19100
G*g*	− 11600	+ 32300	+ 20700

Next, in Fig. 15 (1), conceive the diagonals only in the direction of the counters—they thus suffer compression for a uniform load—and draw the corresponding strain diagram due to dead load only. It is convenient to draw it directly over Fig. 15 (2), as the inclinations of all the pieces (but the diagonals), and also the loads, have been already laid off in proper position. An explanation of the construction for one panel will suffice. Place *b* and *c*, Fig. 15 (1) on either side of the diagonal from A*b* to *ce*, so that the bow piece is M*b* and the chord piece B*c*. Then in Fig. 15 (2) extend *ab* to intersection with M*c*, and draw *cb* ‖ *cb* (1) to intersection with B*b* prolonged; then *ab* = −18300 gives the strain in the first vertical due to dead load. Similarly we proceed for other panels. The strain diagram for Fig. 20, inverted, applies here exactly. The strains in the counters due to dead load are obtained from the same figure.

Since, when the live *load extends to the nearest abutment* the counter connecting with the post is alone in action, we must add the strains on the posts found from Fig. 16, for this case, to the strains just found on the diagonals in the direction of the counters, due to dead load. We thus find,

Posts Fig. 16	Dead Load.	Live Load.	Total Strain.
K*k*	− 17800	+ 16500	− 1300
J*j*	− 17000	+ 23000	+ 6000
I*i*	− 16400	+ 27500	+ 11100
H*h*	− 15300	+ 31000	+ 15700
G*g*	− 14000	+ 32300	+ 18300

On comparing this table with the preceding, we see that, in this example, the posts are most strained when the live load extends from the farthest abutment to the foot of the tie connecting with them. The same is true for the main ties, since they can only take tension. The max. strains thus far found are entered in the following table :

142. We have previously found that for dead load the diagonal web members are only slightly strained. If the counters are tightened too much, it would tend to relieve the main ties of strain, but to increase the strains on the posts. Thus if counter *j*K is in action, say it is strained 10000 lbs., then *j*2 acting from *j* towards 2 is opposed to the the resultant of the resistances J*j*, *j*K and *jk*. Hence extend 23 so that 3 will have such a position that a line drawn from it parallel to counter *j*K to intersection, 5, with *j*J will measure 10000 lbs. The force polygon formed, *j*235*j*, gives as explained before, 23, compression on *jk* (greater than before), 35, tension on counter (10000 lbs.) and 5*j* compression on post J*j*, considerably greater than before.

Hence an ignorant tightening of the counters may easily double or treble the strain on the posts for which they will be designed in what follows.

Another very objectionable feature in this truss, is the fact that for a uniform load there is tension only in the verticals, whereas, when the train is only partially on the bridge, they are each in turn subjected to compression; changing thus quickly from a possible 45000 lbs. tension to a max. compression of 20000 lbs. (about, for middle posts), or the reverse. The verticals were consequently designed, each to consist of two plates connected by the usual latticing and angle irons of sufficient section to resist both strains, and were of course "hinged at both ends."

143. We thus see that the great saving in the web in this form of truss is really the greatest objection to it, at least for a railway bridge. The bow form is best used in the plate girder.

144. The successive *reactions* at the right abutment in last Fig. are easily found from *eq.* (5), art. 19, by making the dead load, $p=o$. The reactions are the same then as the shears on the right segment. Expressing them in hundred weight, we have

$S_1 = 1391$, $S_5 = 664$, $S_9 = 158$
$S_2 = 1188$, $S_6 = 516$, $S_{10} = 92$
$S_3 = 1000$, $S_7 = 383$, $S_{11} = 39$
$S_4 = 825$, $S_8 = 264$, $S_{12} = 0$

Due regard was paid to the rear engine moving off the bridge by modifying the formula as suggested in art. 19.

145. Combining the max. strains found on the main ties due to live load with those previously given due to dead load (art. 137) the results are entered,

BOW STRING GIRDER—THROUGH BRIDGE.

Piece.	d	$\frac{l}{d}$	th.	Strain.	θ	b	Area.	Len'th	No.	k	Weight.	Totals.
	″		″								lbs.	
A*b*	13½	17.7	1 7/16	427000	.39	8000	53.4	19.6	4	1.0	13955	
bc	“	16.		413140	“	9040	45.7	18.3	“	“	11151	
cd	“	“		404370	“	“	44.7	17.5	“	“	10430	
de	“	“		396330	“	“	43.8	17.1	“	“	9986	
ef	“	“		388780	“	“	43.	16.8	“	“	9632	
fg	“	“	1⅛	381660	“	“	42.2	16.7	“	“	9396	64550
*PostK*k	5	33⅓	½	1200	0	3000	0.	17.3	“	“	0	
J*j*	7		9/16	11000	0	“	3.7	23.	“	“	1135	
I*i*	8		11/16	16300	0	“	5.4	26.9	“	“	1937	
H*h*	9		“	19100	0	“	6.9	29.2	“	“	2492	
G*g*	9		“	20700	0	“	6.9	30.	2	“	1380	6944
Latticing, angles, &	c. 37 lbs. pr. ft.							111.4	4	“	12032	12032
Lower Chord				2263400	.39	10420	217.2	10.0/6	4	“	48267	48267
Tie K*l*				34200	0	7500	4.6	19.3	“	“	1184	
J*k*				41000	0	“	5.5	24.	“	“	1760	
I*j*				46000	0	“	6.1	28.5	“	“	2318	
H*i*				49900	0	“	6.6	31.8	“	“	2798	
G*h*				51300	0	“	6.8	33.7	“	“	3055	
Counter F*g*				50200	0	“	6.7	34.3	“	“	3064	
E*f*				48000	0	“	6.4	33.7	“	“	2876	
D*e*				43200	0	“	5.8	31.8	“	“	2459	
C*d*				43100	0	“	5.8	28.5	“	“	2204	
B*c*				44200	0	“	5.9	24.2	“	“	1903	
Vertical Ties				45000	.13	8470	5.3	121.2	“	“	8565	32186

* The thickness of metal “th” is made up of that due to the vertical acting as a tie (5.3) + that due to its acting as a strut.

together with the strains on the other members of the bridge in the adjoining table; from which we deduce as before the

BILL OF MATERIALS.

Bow String Through Bridge, 200′ span, 30′ rise.

	lbs.
Bow and posts, with latticing &c..	83526
20 p. c.	16705
Chord ties and counters	80453
15 p. c.	12068
Other items as in art. 47	134100
Total weight of bridge	326852
Assumed weight	336000
	9148

146. We have assumed the same percentages and estimates of loops, transverse bracing &c., as previously given for the Triangular and Whipple bridges, which is only approximately correct.

The bow piece can be more conveniently constructed of some other form than the phoenix column, so that the above estimate is favorable to this form of truss. The principal objection urged to the Bow String Girder is, that the web members are so slightly strained from dead load, that the rolling load may find them out of action, thus giving rise to hurtful vibrations.

The difficulty in cross-bracing the bow is also a great objection to this truss as a through bridge.

147. In the previous investigation of the Bow String Girder, only one system of triangulation was assumed and the

most economical height was not found as for the other trusses examined.

As the web is comparatively light and some of the ties have about their most economical inclination, 45°, it is not probable that a double system of triangulation, for the span and panel length assumed, would involve as much saving as we found in the quadrangular truss.

The height assumed, 30 feet, is slightly greater than for the beam trusses, as it was thought that the light web would admit of a greater height. Trial only can determine the most economical height. It would seem that the change of a foot or so would effect a very slight saving however, if we may judge at all from the previous investigations concerning the beam trusses.

148. *Analytical Formulæ.*

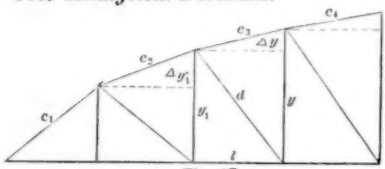


Fig. 17

Let us call the successive lengths of the bow, $c_1, c_2, \ldots$; the length of a post y, the length of the post to left of it y_1; d the length of a diagonal connecting y and y_1; Δy_1 = difference between y_1 and the length of the post to the left of it; $\Delta y = y - y_1$. Also the pieces can be designated by the letters next them on the figure above, prefixing the words *post*, *tie* or *piece* to avoid any confusion.

Call the *moment* of the external forces (reactions and loads) on one side of *post* y, about its foot as a center of moments, M_y; similarly for M_{y_1}; also call the *shear* in the panel included by y and y_1, *for the same distribution of the load* S_y.

Designate a panel length by l; the inclinations of pieces $c_1, c_2, \ldots$ by $a_1, a_2, \ldots$ and of the diagonal d by β.

Also denote the strains in c_3, y, d, etc., by the corresponding capital letters, C_3, Y and D.

149. Suppose a vertical section cutting pieces c_3 d and l, and take the intersection of d and l as a center of moments to find the strain C_3, whose lever arm is thus, $y \cos a_3 = y \frac{l}{c_3}$

$$\therefore M_y = C_3 y \frac{l}{c_3} \quad \therefore C_3 = \frac{M_y}{y} \frac{c_3}{l} \quad \ldots (1)$$

If we supply forces (as in art. 7, Fig. 2) at the supposed vertical section (cutting c_3 d and l) *equal and directly opposed* to the resistances of the cut pieces, we must have the algebraic sum of their vertical components equal to S_y. Compare art. 8. Now since the bow is always in compression—since every weight on the truss causes an upward moment—the external force opposed to the resistance in piece C_3 acts downwards.

$$\therefore S_y = D \sin. \beta + C_3 \sin. a_3 = D \frac{y_1}{d} + \frac{M_y}{y} \frac{c_3}{l} \frac{\Delta y}{c_3}$$

$$\therefore D = \frac{d}{y_1} \left(S_y - \frac{M_y}{y} \frac{\Delta y}{l} \right) \quad \ldots (2)$$

On the right half of the truss the force opposed to C acts upwards. Since Δy is then minus eq. (2) applies on changing the sign of Δy. Again, note that when S_y is minus it must be so substituted in eq. (2). When D is plus, the diagonal is in tension, otherwise in compression.

The reader will do well to sketch the truss up to the section and the forces acting on it, as in Fig. 2, in this and subsequent articles.

150. Next conceive the section parallel to diagonal d, cutting pieces c_2 y_1 and l; and balance the vertical components of the "acting forces," which include the reaction and loads left of the section, and the supposed forces equal and opposed to the resistances of the cut pieces

$$\therefore S_y = Y_1 + C_2 \sin. a_2$$

From eq. (1) we can derive,

$$C_2 \sin. a_2 = \frac{M_{y_1}}{y_1} \frac{c_2}{l} \frac{\Delta y_1}{c_2} = \frac{M_{y_1}}{y_1} \frac{\Delta y_1}{l}$$

Now $M_{y_1} = M_y - S_y l$, as may be shown as follows:

Suppose a section cutting y, c_2 and the chord piece to right of piece l; and supply forces equal and opposed to the resistances of the cut pieces. Decompose the applied force $= C_2$, at top of post y, into vertical and horizontal components. The latter component is equal to the force applied at the cut chord piece and forms with it a left-handed couple, equal to M_y, since the moment of the vertical component $+Y = S_y$ is zero; these forces

acting through the center of moments—the foot of post y.

Hence, regarding the left-handed couple ($=M_y$) and the sum of the vertical components ($=S_y$), acting downwards if S_y is $+$, as the external forces at the section, we have the *moment* about the foot of post y_1, $M_{y_1}=M_y-S_y l$ as was to be proved.

It is useful to note that, since $M_y=M_{y_1}+S_y\,l$, the moment increases in going from y_1 to y, so long as S_y is positive. Therefore at the point where $S_y=0$ the moment is a maximum (compare art. 90).

Substituting the above value for M_{y_1}, we have for the strain in the post y_1

$$Y_1=S_y-\frac{M_y-S_y\,l}{y_1}\,\frac{\Delta y_1}{l} \quad \ldots \quad (3)$$

As before, when S_y or Δy_1 are negative, they must be so substituted in this formula.

151. *The Maximum Strains* on a tie we have previously found to be when the load extends from the foot of the tie to the farthest abutment; for a counter tie, the load extends from its foot to the nearest abutment. Therefore, for maximum strains, the shears S_y are easily obtained from eq. (5), art. 19.

The corresponding moments M_y are found thus: to S_y add the dead load between the post marked y and the left abutment to find the *reaction*, whose moment about y, minus the moment of the downward loads from the abutment to y gives M_y.

152. *Example.* Required the max. strain, D the counter $\overline{iJ}$ ever sustains, for the bow string girder, Fig. 16 previously examined. The live load extends from M to J. By table, art. 21, $S=-19172$. Reaction at $A=-19172+8\times14000=92828$.

$$\therefore\ M_J=92828+150-112000\times75=5{,}524{,}200,$$

whence by eq. (2)

$$D=\frac{31.8}{26.9}\left(-19172+\frac{5524200}{23}\,\frac{3.9\times6}{100}\right)=43770.$$

The graphical analysis gave 43200.

153. For a post as $\overline{Ee}$, the live load must either extend from M to F or from A to D to cause max. strains. In the first case the strain on $\overline{Ee}$ is by eq. 3.

$$Y_1=87364-\frac{9613667-87364\frac{100}{6}}{26.9}\cdot\frac{3.9\times6}{100}=16402$$

Secondly, since post $\overline{Ii}$ for live load from M to J sustains the same strain as $\overline{Ee}$, when the load extends from A to D, we have for the strain in this case,

$$Y_1=-19172+\frac{5524200+19172\frac{100}{6}}{26.9}\cdot\frac{2.3\times6}{100}=10808$$

The graphical analysis gave 16,300 and 11,100 respectively. In this way we can form the following table; where column 1 gives the post, columns 2 and 3 the strains sustained by it, when the live load extends from the foot of the tie or counter connecting with it to the farthest or nearest abutments respectively:

Cc	1600	comp'n	182	tension
Dd	9318	"	6200	comp'n
Ee	16402	"	10808	"
Ff	19008	"	17150	"
Gg	18470	"	18470	"

In this case, we see that the posts are most strained when the live load extends to the farthest abutment. The strains found by the preceding formulae were found to differ from those found by construction less than 1000 lbs. as a mean, the extreme difference being 3000 lbs. This is due partly to the short lengths of the bridge members from which their inclinations were derived, and partly from the unavoidable errors of construction, as well as from the dimensions being taken to only tenths of a foot in the formulae. Other formulae could be given but we have preferred those of Schwedler on account of their compactness and as introductory to his bridge.

154. *The Schwedler Bridge.*—In this bridge, the upper chord is parallel to the lower chord in those panels where counters would be required in a Pratt or a Howe truss; *e.g.*, for the four middle panels, for the span, panel length and loads previously considered. In the other panels, the height of post is so regulated that no counters are required; *ie.*, the diagonals act as ties only or as struts only.

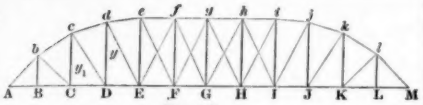


Fig. 18

Now the max. reverse strain, in a diagonal as $\overline{Dc}$ (Fig. 18), is when the front engine is at C and the load extends to A. The condition for this truss is, that this strain must be zero for those panels where no counters are to be used. Placing *eq.* (2) equal to zero, we deduce, for the left half of the truss,

$$\triangle y = y\frac{S_y\, l}{M_y} \quad \ldots\ldots\ldots (4)$$

In this formula, it is understood that the front engine is at the post marked y_1, and the live load extends to the left abutment, the moment M_y being taken about the post y.

155. *Example.*—Take the span=200, $l=\frac{100}{6}$, loads &c. as before. Assume $Ec=30'=y$.

With engine at D and load extending to A, the moment about E is

$$M_y=5{,}844{,}000 \qquad S_y=-19172$$

$$\therefore \triangle y=-30\frac{19172\times\frac{100}{6}}{5844000}=-1.6$$

$$\therefore Dd=30-1.6=28.4 \text{ feet.}$$

Again, write $y=28.4$, with load from A to C, $M_y=4{,}525{,}000$ and $S_y=-39836$, whence by (4) $\triangle y=-4.1$ $\therefore$ $\overline{Ce}=24.3$ finally put $y=24.3$, $S=-59112$, with live load at B only, the moment about $C=M_y=2{,}981{,}000$ $\therefore$ $\triangle y=-8$, whence $Bb=24.3-8=16.3$.

156. Should more concentrated loads *ever* be allowed to pass over the bridge, the posts should be increased in length for them, otherwise the destruction of the bridge is inevitable. It should therefore be proportioned for a greater load than can ever by any possibility come on it, which would somewhat lessen the economy shown below.

157. The max. strains on ties and posts are found by using eqs. (2) and (3) as previously explained, the load extending to the farthest abutment for the posts.

The minimum strain on the first and last three diagonals is zero, for this truss; the same is true for the posts at their feet, since the vertical strain is transmitted to one by the other entirely.

158. The computation of some of the web members will now be given.

Max. strain in $\overline{bC}$ is when engine is at C and load extends to M. In eq (2) write $d=\overline{bc}=23.3$, $y,=B\overline{b}=16.3$, $y=\overline{Ce}=24.3$, $\triangle y=8$ &c., whence max. strain in

$$bC=\frac{23.3}{16.3}\left(181840-\frac{6294667}{24.3}\frac{8}{\frac{100}{6}}\right)=82{,}131$$

$\triangle y$, $\triangle y$, become zero for some of the center panels, reducing the case to that of the Pratt truss.

From eq. 3 the max. strain in post $\overline{Cc}$, (load from M to D) is,

$$148960-\frac{8{,}148{,}000-148960\frac{100}{6}\;8\times 6}{24.3\qquad\qquad 100}$$
$$=37060.$$

159. The chord strains are determined as explained for the Bow String. The lever arms of C_2, C_3, C_4, as determined from a drawing, are 21.9, 27.6, 29.9 respectively.

160. The results for the Schwedler truss of 200′ span 30′ center height, &c., are entered in the following table:

(*See Table on following page.*)

BILL OF MATERIALS.

Schwedler Bridge, (through) 200′ span 30′ high.

	lbs.
U. chord and posts	78,574
20 p. c.	15,714
Ties and lower chord	65,801
15 p. c.	9,870
Other items as in art. 47	134,100
Total weight of bridge	304,059
Assumed weight	336,000
	31,941

161. Collecting together the estimates of weights of the *through* bridges examined, arts., 108, 128, 145 and 160, we have, in round numbers,

Weight of	Triangular	Truss,	325000 lbs.
" "	Whipple	"	325000 "
" "	Pratt	"	333000 "
" "	Fink	"	356000 "
" "	Bow String	"	327000 "
" "	Schwedler	"	304000 "

The pier towers of the Fink were put at 27000 lbs. These weights will differ still more on a re-estimate, on assuming dead loads more in accordance with the truth.

SCHWEDLER THROUGH BRIDGE—TABLE OF WEIGHTS.

Piece.	d.	$\frac{l}{d}$	th	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″				□″	′			lbs.	
*Bow C_1	13⅓	21		308910	.39	7650	40.4	23.3	4	10/3	12551	
C_2	"	16	13/16	298060	"	9040	32.9	18.5	"	"	8115	
C_3	"	"		317930	"	"	35.2	17.2	"	"	8072	
C_4	"	"		345960	"	"	38.3	16.7	"	"	8528	
C_5	"	"		374530	"	"	41.4	100/3	"	"	9200	
C_6	"	"		381660	"	"	42.2	"	"	"	9378	55844
*Post Cc	9⅔	30	5/16	37060	0	3930	9.4	24.3	"	"	3045	
Dd		"	3/16	54466	0	"	13.8	28.4	"	"	5225	
Ee	12	"	7/16	61260	0	"	15.6	30	"	"	6240	
Ff	12	"	"	58648	0	"	15.	30	"	"	6000	
Gg	9	40	"	31320	0	2810	11.1	30	2	"	2220	22730
Tie Bb				45000	.13	8470	5.3	16.3	4	"	1152	
Cb				82131	0	7500	11.	23.3	"	"	3417	
Dc				94830	0	"	12.6	29.4	"	"	4939	
Ed				101860	0	"	13.6	32.9	"	"	5965	
Fe				99886	0	"	13.3	34.3	"	"	6082	
Gf				67054	0	"	8.9	"	"	"	4070	
Counter Hg				35809	0	"	4.8	"	"	"	2195	
Ih				6151	0	"	2.	"	"	"	915	28735
Chord AC				221020	.39	10420	21.2	100/3	"	"	9422	
CD				268630	"	"	25.8	100/3	"	"	5733	
DE				308970	"	"	29.6	"	"	"	6578	
EF				344808	"	"	33.1	"	"	"	7355	
FG				374530	"	"	35.9	"	"	"	7978	37066

* The compression members are regarded as Phœnix columns in the computation, though other forms may be more convenient in construction. C_1 was taken as "hinged at one end," the other chord panels as "flat at both ends," the posts as "hinged at both ends."

The superiority of the Schwedler Truss in point of weight is marked, and should receive careful attention from constructors.

162. Several other through trusses were examined, as the Lenticular or Fish-bellied Girder, and the Triangular, with two suspenders to a panel, instead of one; but little or no economy was found over the Whipple Truss above. The truss figured in VAN NOSTRAND'S MAGAZINE, for November, 1877, p. 461 (Fig. 8), on data above, weighs 320,000 lbs.

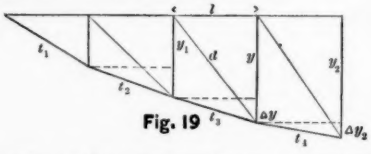


Fig. 19

163. BOW STRING DECK BRIDGE.—*Formulae.*—Call the bow pieces $t_1, t_2 \ldots$; the length of the post to the right of y, y_2; put $y_2 - y = \Delta y_2$; the other notation as before.

The strain in piece t_4 is, $T_4 = \frac{M_y}{y}\frac{t_4}{l}$ . . . . . (5), since the lever arm of piece t_4 about the top of post $y = y\frac{l}{t_4}$.

164. Now conceive a vertical section cutting pieces l, d and t_3, and balance the vertical components.

$$\therefore S_y = D\frac{y}{d} + T_3\frac{\Delta y}{t_3} = D\frac{y}{d} + \frac{M_y - S_y l.}{y_1}\frac{t_3}{l}\cdot\frac{\Delta y}{t_3}$$

$$\therefore D = S_y\frac{d}{y} + S_y\frac{d}{y}\frac{\Delta y}{y_1} - \frac{dM_y}{y_1 y}\frac{\Delta y}{l}$$

$$\therefore D = \frac{d}{y}\left(S_y - \frac{M_y}{y}\frac{\Delta y}{l}\right) \ldots\ldots (6)$$

To the right of the center, Δy is minus, whence the $-$ sign in the $(\ )$ is changed to $+$ as is evidently correct.

165. Next conceive a section parallel to piece d, cutting pieces l, y and t_4, and balance the vertical components of the

forces opposed to the resistances of the cut pieces with S_y we find,

$$Y=S_y-T_s\frac{\triangle y_s}{t_s}=S_y-\frac{M_y}{y}\frac{\triangle y_s}{l}\ldots\ldots(7)$$

The same formula applies to the right of the center, since $\triangle y_s$ is then minus and the eq. becomes

$$Y=S_y+\frac{M_y}{y}\frac{\triangle y_s}{l},\text{ where }\triangle y_s=y-y_s$$

When S_y is minus it must be so regarded in the previous equations.

As the application of the formulae is essentially as just explained for the through bridge it is needless to give it.

166. As it was of special importance to ascertain whether the posts were most strained by the live load extending to the farthest or nearest abutment from the posts considered, for the loads &c. as previously given, the following strains were tabulated referring to the next figure:

Post.	Live Load from Post to farthest abt.	Live Load from Post to nearest abt.
ab	50718	60655
cd	57400	60584
ef	66060	62970
gh	70108	68450
ij	71564	71750
kl	73632	73632

from which we ascertain that *in this case* $\overline{ab}$ and $\overline{cd}$ are most strained when the live load extends to the nearest abutment; for the other posts it extends to the farthest abutment.

167. In this deck truss the constructive difficulty of the joints of the bow is not experienced as the bow is not in tension. The web is heavier and the posts may be made of phoenix columns, with *square* joints at their connections with the chord. These vertical members now bear but one kind of strain; altogether the truss is a good one, and is worthy of more consideration than it has received, as it will be found to be the most economical in weight of any of the deck bridges examined.

168. *Graphical Analysis*—The next figure gives the form of the truss, omitting the counter ties, and the strain diagram for the uniform dead load of 14000 lbs. per panel; which, using Bow's admirable notation, needs no further explanation. From the strain diagram we find the dead load strains on ties, *bc*, *de*, *fg*, *hi*, *jk*, respectively, to be, in round numbers, 6000, 5000, 4000, 3000 and 2000 lbs; the strains on the posts vary from 18000 on *ab* to 14000 lbs. on *kl*.

169. If the members of the *bow* in any bow string truss are given such inclinations that the strains on the web ties are zero, *i. e.* that in the strain diagram *b* and *c* coincide, as well as *d* and *e*, *f* and *g* &c., then the apices of the bow are points in a parabola. For in the *strain diagram* the points *a*, *b*, *c*, *d*, *e*, ... will all lie in the vertical through *a*, and then since $ab=bd=dg\ldots$, the *difference* between the *tangents* of the inclinations to the horizontal of any two consecutive bow pieces is the same. For regarding momentarily Δa as unity, $ab=bd=dg=\ldots$ is the tangent difference in question. This is a property of the parabola Thus assume its equation $y^2=mx$; give x the increment h and call the corresponding increment of y, k. $\therefore (y\times k)^2=m(x\times h)$. Whence, expanding and taking the difference between the two equations, $2yk+k^2=mh$

$$\therefore\frac{h}{k}=\frac{1}{m}(2y+k)$$

Now $\frac{h}{k}$ = tangent of the angle made by a chord of the parabola with the axis of y. (In the figure of the truss a horizontal drawn through the point Mjm (the origin) may be taken as the axis of Y, the line *kl* as the axis of X).

Now giving to y the successive values o, k, $2k$, $3k$ . . . . we find for $\frac{h}{k}$ the successive values,

$$\frac{1}{m}k,\ \frac{1}{m}3k,\ \frac{1}{m}\ 5k,\ \frac{1}{m}\ 7k,\ldots.$$

whose difference is $\frac{1}{m}2k$, *a constant*, which was to be demonstrated.

In the figure of the truss k may be regarded as equal to a panel length $16\frac{2}{3}$ feet, whence h will be the vertical distance between the extremities of the bow piece, the tangent of whose inclination to the horizontal is given by the value of $\frac{h}{k}$, corresponding to the value of y for the lower end of the bow member.

When a parabolic bow string is loaded uniformly the strain throughout the string is uniform, since, in the strain diagram *a*, *b*, *c*, *d* . . . are in the same vertical.

170. As before, to find the max. strains due to live load only on tie 14, we suppose the front engine at IJ and the train extending to the farthest abutment. Lay off the reaction at LM from 1 to 2, and draw 23 parallel to chord to intersection with 13 passing through LM. Then 13 = resultant of reaction and strain in chord panel J, must be in equilibrium

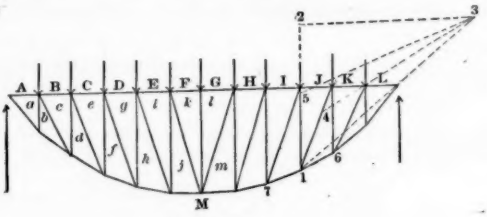
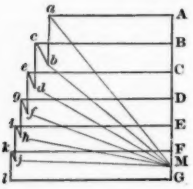


FIG. 20.



with strains in tie 14 and 16; hence drawing 34 parallel to 16, 14=strain on tie due to live load.

Similarly, drawing 35 parallel to 17, 15=strain on post 15 *due to this position of the load;* but we shall find that the posts are most strained *from the live load alone* when it extends from the *nearest* abutment to the post considered; which strains as well as the strains on the counters are determined in a similar manner to the above. Now add the post strains due to live load—extending to farthest abutment—to dead load strains obtained from diagram above, and compare these totals with those found, by adding the post strains due to live load —extending from post to nearest abutment to those found (from a diagram similar to Fig. 15 (1) and (2) inverted), due to dead load, from a figure where diagonals in the direction of counters are alone represented.

We reach the conclusion of art., 166.

From the last mentioned diagram, the dead load strains on counters are found.

171. The total strain on any post cannot be less than 45000 lbs., (the panel reaction), when the engine is directly over it; and proceeding as above we find that the strain on the posts due to live and dead load is not in any case less than 45000 lbs.

Suppose that the loads are so placed that AB has, say, double its value given in the figure, the reaction MA remaining the same; then in the strain diagram for *a*B, *ba* AC*c'b* (*c'* being in the prolongation of *bc* at its intersection with C*e*) we see that *bc* must now act as a strut; *otherwise ab* takes the whole load (2 AB) and a counter must be introduced from its foot to *c*C.

It follows that, for the assumed truss, the counters next an engine *may* be in action when the whole bridge is loaded.

172. *The maximum chord strains* are, for panels $\overline{Aa}$, Bc, $\overline{Ce}$, ... respectively, $\frac{M_1}{9.8}, \frac{M_2}{17.3}, \frac{M_2}{23}$ . . . .; the lever arms being respectively $\overline{ab}$, $\overline{cd}$, $\overline{ef}$, ...

For the Bow we ascertain the lever arms as follows: conceive the panel as M*dec* cut, take the intersection of the tie and upper chord panel *c*C as a center of moments, and from it draw a perpendicular to M*d* produced, which is thus the lever arm of the strain in M*d*. In this case M_2 divided by this lever arm is the strain in M*d*, M_2 being the maximum moment when *c*C is taken as the center of moments.

The max. moment for both M*a* and M*b* is M_1; hence M_1 divided by the length of perpendiculars from *a*B to M*a* and M*b* respectively give the strains in M*a* and M*b* respectively.

Similarly for other divisions of the bow.

173. The strains are entered in the following table. For the posts, θ was taken at .25 as an average, from which none of them differ much. For the ties

BOW STRING GIRDER—DECK TRUSS.

Piece.	d.	$\frac{l}{d}$	th.	Strain.	θ.	b.	Area.	Length.	No.	k.	Weight.	Totals.
	″		″									
Chord, c_1.....	$13\frac{1}{2}$	15	$1\frac{1}{12}$	367620	.39	9050	40.6	$12\frac{0}{8}$	4	$\frac{10}{8}$	9022	
c_2.....c_6.....	"	"		1909820	"	9270	206.	"	"	"	45778	54800
Post ab.....	8	"	$\frac{5}{16}$	59000	.25	8140	7.2	9.8	"	"	941	
cd.....	8	26	$\frac{7}{16}$	60800	"	5950	10.2	17.3	"	"	2353	
ef.....	10	27.6	$\frac{9}{16}$	66000	"	5830	11.3	23.	"	"	3466	
gh.....	$10\frac{13}{16}$	30.	$\frac{7}{16}$	71400	"	5290	13.5	26.9	"	"	4842	
ij.....	$11\frac{5}{8}$	30.	$\frac{5}{8}$	73900	"	5290	14.	29.2	"	"	5451	
kl.....	12	30.	$\frac{5}{8}$	73600	"	5290	14.	30.	2	"	2800	19853
t_1				426860	.39	10420	41.	19 6	4	"	10715	
t_2				407550	"	"	39.1	18.3	"	"	9543	
t_3				400470	"	"	38.4	17.5	"	"	8960	
t_4				395270	"	"	37.9	17.1	"	"	8641	
t_5				390350	"	"	37.4	16.8	"	"	8377	
t_6				387440	"	"	37.1	16.7	"	"	8258	54494
Tie bc.....				45000	0	7500	6.	24.2	"	"	1936	
de.....				50000	0	"	6.7	28.5	"	"	2546	
fg.....				52000	0	"	6.9	31.8	"	"	2925	
hi.....				54000	0	"	7.2	33.7	"	"	3235	
jk.....				54000	0	"	7.2	34.3	"	"	3293	
Counter 1.....				49500	0	"	6.6	33.7	"	"	2966	
2.....				45200	0	"	6.	31 8	"	"	2544	
3.....				39800	0	"	5.3	28.5	"	"	2013	
4.....				37000	0	"	4.9	24.	"	"	1568	
5.....				35300	0	"	4.7	19.3	"	"	1209	24235

θ is put at o. The maximum chord strains are Aa=367620, Bc=377320, Ce=381510, Dg=384540, Ei=384790, Fk=381660; the sum of the last five being 1,909,820, as entered in the table. The total weight found is the same whether these chord panels are considered separately or collectively, the length being the same for each piece.

BILL OF MATERIALS.

Bow String Deck Truss, 200′ span, 30′ center depth.

	lbs.
U. chord	54800
Posts	19853
20 p. c. on two last	14930
Bow	54494
Ties	24235
15 p. c. on two last	11809
Other items (art. 91)	127230
Total weight	307351
Assumed weight	336000
	28,649

174. The *Triangular*, Fig. 7 as a Deck Truss, can be best compared with the Whipple, etc., with vertical end posts. However, let us assume the abutments built up to grade to compare with the deck trusses examined. The max. strains are identical with those for the through bridge, except that the vertical posts must now sustain a max. load of about 45000 lbs. The suspenders may be made of one square inch cross section. Estimating as usual we find its weight as given below:

175. *Comparison of Deck Bridges of 200′ span*, loads, etc., as previously given.

Triangular,	28′	high,	321,000 lbs.
Whipple,	"	"	326,000 "
Fink,	$33\frac{1}{3}$	"	317,000 "
Bow String,	30	"	307,000 "

The Schwedler as a Deck Truss would doubtless prove lighter than any of the previous trusses.

176. With other details than those assumed—and our best bridge companies have devised some excellent ones—the results found may be slightly varied; but it is believed that the general comparisons are correct for any given details. At any rate the data is all given so that

errors can be detected or modifications of design readily made.

177. Although the loads previously assumed are for railroad bridges, yet the formulae, or methods given, can be easily adapted to highway bridges, where the live load is usually taken as so much per square foot of roadway, varying from 35 to 100 lbs. per square foot.

178. A matter of great interest to engineers is the determination of good formulae for compression members. Government aid is anxiously looked for in this direction to institute the proper experiments. Various formulae for different cross-sections are being introduced in some specifications, though they are founded on comparatively few experiments, and thus are only provisional, as indeed are the formulae previously used in this paper for unit strains; but the deduction of Wöhler that a piece will bear a smaller maximum strain the greater the extremes of strain to which it is subjected is not provisional, but a fixed fact, which must be regarded if a bridge is to be designed scientifically; and it is to be hoped that the above will show that there is no difficulty in the application of Launhardt's formula founded on this law.

179. It is believed that there will be no difficulty in applying the preceding principles to any form of truss in ascertaining the greatest or least strain that any member is ever called on to bear. If the truss is composed of two or more web systems, not connected at their intersections, estimate the influence of each separately and combine the effects for a piece that is common to the two or more systems. All the principles relating to the method of ascertaining max. and min. strains, etc., that pertain to a simple system apply to each web system in turn.

UNIFORMITY IN SANITARY ENGINEERING.

From "The Engineer."

We admit that there are exceptions to every rule, and that it is impossible to lay down a hard and fast line, to be adhered to undeviatingly in any branch of the profession. Nevertheless the greater the number of instances to which a general rule can be made applicable, the less troublesome, and what is infinitely more important, the more certain becomes the task of the engineer. By the phrase "less troublesome" we do not mean to imply that the work of an engineer, in a sanitary or other point of view, is to be devoid of trouble and anxiety, but simply that he is fairly entitled to be relieved from any amount of trouble which is, in reality, incurred merely for trouble's sake. Under the latter category may be included unnecessary, and frequently useless routine work, and the planning and execution of schemes which in some cases are nothing better than crude experiments, undertaken to meet contingencies which might readily be provided for by existing arrangements enforced by a proper head or central administration. We are not now about to advocate the creation of a chief or central sanitary authority for large districts, although it may be a matter for consideration whether the important object included in the title of our present articles might not be greatly promoted by the establishment of such an authority.

It cannot fail to strike anyone who is acquainted with the various drainage and sewerage systems prevailing in different towns, that some must possess advantages over others, advantages which are general, and not peculiar to the town or district to which they pertain. It is just possible that there may not be any two towns or districts placed under precisely identical conditions of either nature or art, but there are undoubtedly a large number which are to all intents and purposes, practically so located. To all these, therefore, one and the same uniform system of drainage and sewerage might be applied provided only that a selection could be made of the system presenting the best general advantages. Considerable latitude must be allowed, and great discre-

tion used in determining such a selection. Hitherto in some instances so-called compulsory injunctions have been made, and pretended fines imposed, when compliance with the demands of the authorities was utterly impossible. The case of Kingston-on-Thames, which occurred some two years ago, was of this character, in which the penalties incurred, for non-compliance with the injunction granted to the Thames Board of Conservancy, amounted to the equally decisive and preposterous sum of £10,000. It is needless to add that the penalties were never paid, but it is certainly not creditable to our sanitary legislation that such penalty should either have been incurred by the one party, or inflicted by the other. The carelessness and indifference of the former in incurring it is equalled only by the folly and impotency of the latter in inflicting it.

The statistics of large towns prove that no one system for the disposal of sewage can be rendered universally applicable; but they do not prove that the same rule, of necessity, applies to the collection and removal of it from human habitations. With respect to the latter, if we choose to beg the question, the one universal system would be found in that of water-carriage, which unquestionably conveys the sewage from the vicinity of dwelling-places in the quickest, the cleanest, and in the manner the least offensive to our English habits and prejudices. It is worth noting that, at the conference on the health and sewage of towns held last year, it was one of the "resolutions" arrived at, that, "for use within the house no system has been found in practice to take the place of the water-closet." If this is the case, it could tend very much to the desired uniformity in sanitary engineering if that system of collection and removal were rendered compulsory in all instances where good cause could not be shown against it. This would be the more advantageous, ina-much as there is only one method or plan upon which the wet or water carriage system can be applied, whereas there are several methods by which the dry system can be brought into operation. Of those different methods it is not easy to determine which is the best. It would appear that recent experiments demonstrated that of them all—and they are all more or less offensive—the pail system is perhaps the least objectionable, especially in large towns. Upon whatever plan the dry system may be carried out its efficient working depends entirely upon the way it is managed. It possesses none of the automatic advantages of removal belonging to the water carriage principle. The contents of privies, ashpits, middens, cesspools, tubs and pails, must be removed by manual labor and transported to their destination along the streets and public thoroughfares. The pneumatic plan, which is adopted in some of the towns of Holland, is an exception to the latter statements or, rather, it would be, were it a genuine dry system. But the pneumatic system deals with a certain quantity of liquid as well as solid sewage. It is, moreover, both complicated and expensive in construction and working arrangements, easily deranged and put out of order, and troublesome and difficult to repair. One of our first sanitary engineers has remarked on this plan that he did not "know one English town in which the apparatus, if adopted, would be other than a costly toy."

To return to the suggestion made at the commencement of our article, with relation to the establishment of large central sanitary authorities or boards, it is obvious that had such authorities existed during the "precipitating mania," happily now over, it is not too much to assert that enormous sums of money would have been saved by both willing victims and unwilling ratepapers. It might be well asked, of what use are Government Commissions, whose labors are carried on at the expense of the community, if the results they arrive at are to be permitted to be totally ignored, and processes which they unanimously and unequivocally condemn are allowed to be put into practical operation, at the cost of those who, however reluctant to pay, are powerless to prevent the imposition of the tax. Assuming that the centralization of sanitary administration were an advisable proceeding, the first difficulty to be surmounted would consist in the selection of a standard or unit of area over which any central authority should have sole jurisdiction. It is absolutely necessary that the unit should be large, in order that some

uniformity at least should result from the administration, and a termination be put to the evils which attend the present condition of affairs in which every "sewer authority," no matter how small may be the field of its operations, can do what seems best in its own eyes. Were the results of bad and defective sanitary arrangements to be confined to the particular district or locality in which they originated, the matter might be left in the hands of the sewer authority of that district to be dealt with. But this is frequently not the case. At present, owing to the want of boards of conservancy, rivers and streams which are preserved from pollution along certain portions of their course, are not so preserved in others. It is becoming every day more and more apparent that we shall be compelled to increase the scale upon which the sanitary engineering of the country is conducted. The water supply—the most important feature in the whole of sanitary administration—of many of our large towns is lamentably deficient in both quantity and quality. The fact is that the original sources of supply are no longer adequate to meet the ever-increasing demands made upon them. The Thirlmere scheme as a new source for the supply of water to Manchester is a case in point. It may be remarked here that there are comparatively few water-closets in Manchester. They are discouraged as much as possible by the local authorities, who practically restrict the use of them to houses of the better class. If Manchester had been drained and sewered similarly to London, on the water carriage principle, it would have required a better supply of water long before the present time.

It has been proposed that the unit of area referred to should comprise a county, and we do not think this would be found in any degree excessive. There is a good deal to be said on both sides of the question, but there is no doubt that the establishment of central or district boards would tend to the reformation of our present sanitary legislation. They would do away with a number of inferior local boards and officials, professional and otherwise of very limited qualifications and attainments, and, in their stead, substitute uniformity, efficiency, and economy. There is one point which deserves the serious consideration of the present Local Government Board, or any future head or central sanitary authority. It is the position of the engineer and surveyors to local boards. The tenure of their office depends upon the will, and frequently the caprice of their respective boards. It ought to be similar to that of the medical officer, who has the right to appeal to the chief authority in case of dismissal by the board.

A HISTORY OF DEEP BORING, OR EARTH BORING, AS PRACTISED ON THE CONTINENT.

By Mr. J. CLARK JEFFERSON, A. R. S. M.

A Paper read before the Midland Institute of Mining Engineers.

The writer observed that in bringing under the notice of the members of the Institute a short history of deep boring, or earth boring, which has been, and was still, carried on on the Continent, he believed he should be able to point out many inventions and arrangements which were quite new, and not unworthy of the attention of most of the members. The outcrop of the coal measures in this country, the comparatively small depth and level character of the coal seams, has hitherto not made such great claims on the art of boring as on the Continent, where lying mostly under newer formations and at great inclinations, necessitated deep borings previous to the commencement of sinking operations. Lately, however, in this country they had witnessed the searching for coal under formations newer than containing the coal measures. The Wealden borings in Sussex were, perhaps, the most notable examples. The fact of part of

the Nottingham coal-fields dipping eastward naturally led to the question—whether there would not be some probability of finding coal in the center of Lincolnshire if borings were carried on sufficiently deep. Indeed, the deeper the coal seams lie, the greater will be the need of careful boring to ascertain their depth and character, and it might be that at some future date it would be the lot of some of the members of that Institute to search in a more easterly direction for fresh deposits to supply the exhaustion of seams in the center of the coal measures in West and South Yorkshire. Although he should endeavour to deal with the subject as much as possible in an historical manner, he should consider it under the following heads:

First, the borer or boring apparatus;

And Second, the surface arrangements, and, lastly, the removal of the hindrances occurring during boring, including the lining of bore holes. The first mention of the art of boring was in a book published by Mr. C. T. Delius, in Vienna in 1770, in which they had only the mere mention of earth-boring. It was pretty generally stated that the art of boring was invented by the Chinese, and was introduced from China into Europe by Jobard. Boring may be carried on in two ways, either with the use of rigid rods or with a rope. Until the invention of the diamond rock drill, boring seldom took place in the popular sense of the term, except for small depths of soft strata. The writer went on to point out at great lengths the various methods of boring, together with the apparatus used on the Continent. He remarked that the process of boring as usually carried on consisted of essentially two distinct portions. First, for raising and the letting fall of some heavy tool into the bottom of the bore hole cutting up and breaking the rock into small pieces; and, secondly, in raising the *débris* or sludge from the bottom of the bore hole. Mr. Jefferson went on to point out that the rope and windlass which were first known and used on the Continent are essentially the same as those used in this country. The use of the boring lever is not, however, so common in this country as on the Continent, where all deep borings are generally carried on by its aid. In speaking of the bore or boring apparatus, including the shaft rods, which were sometimes made of iron and sometimes of wood, he said their breakage, especially at the screw joints, was a thing of constant occurrence in deep holes. Rigidity and lightness being required, the use of wooden rods was frequently adopted, they being found to answer much better when the bore hole is full of water. As far back as the 17th century wooden rods had doubtless been used in Russia and Germany. In 1840 Herr Kind invented the lengthening screw which has entirely superseded the use of the chain in deep borings. The arrangements consist of two long side links which are held together at the top by a sort of pin, the nuts screwing on at the ends outside the links. In the year 1831 borings were comenced at Neusalswerk, in Westphalia, for salt, Herr B. Von Ocynhausin being director of the trials. In 1834 when a depth of 900 feet had been reached, obstacles proved to be insurmountable, although 1300 feet more were required to reach the deposits. Whilst things were in that state it occurred to Von Ocynhausin that if he could detach the lower part of the rods—at least, so much as was necessary for an effective blow—he might overcome the obstacles. The result of such a thoughtful and rational consideration was the invention of a very remarkable instrument, known as the sliding shears, or jaws. Kind's free falling borer, which formed an important continental invention in the art fo boring, was employed for the first time by Herr G. C. Kind, in 1844, in boring at Mondorf, on the boundary between France and Luxemburgh. The writer then proceeded to explain that the free falling instrument is composed of two principal parts—viz., the free falling rod and shears. The free falling rod is provided at the upper extremity with a small tongue piece about 2 inches long 1½ inches wide, and 1⅜ inches broad, the bottom part of the rod being ¾ inch broad, and 1½ inches wide immediately below the tongue. About 12 inches lower down two nose pins of steel are inserted, the bottom of the falling rod terminating on a cylindrical portion or neck, to which the lower rods of the boring chisel can be secured.

RAPID METHODS OF LAYING OUT GEARING.

By S. W. ROBINSON, Prof. of Mech. Eng., Ohio State University, formerly of Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

GEAR teeth, more than any other mechanical product, seem destined to suffer for want of correct construction. Advantage seems to be taken of the fact that errors in their peculiar form are not so easily detected as in bodies of more simple shape. No one would dare to leave a hole in a link-rod three-cornered when it is to work on a cylindrical pin. Such a botch would, however, be much less discoverable in its working than errors in gear teeth. In spite of the tale, told loud and long about every such error, makers will still persist in assuming the forms of teeth by guess, because it saves trouble.

There is probably no better way of stopping this abominable practice than by introducing simple and easy methods of laying out the teeth. To point out a few such methods is the leading object of this paper.

The circle arc has been tried as a substitute for the correct, though much more complex curve, the epicycloid, and with results greatly superior to guess curves. But if a curvilinear ruler could be found more approximative to the required curve than the circle, and presenting no greater difficulties in use; it, of course, would be preferable. Such a curved ruler we have in the Templet Odontograph, described at length in this Magazine of July, 1876. The methods of setting there given were intentionally made as free from drawing, and use of instruments, as possible. But the accompanying tables often required interpolations to be made, a thing which most practical men have more difficulty with than with drawing.

But the methods of setting now to be considered are entirely independent of tables and mathematical work, and depend solely upon simple diagrams. The advantage of the latter is very considerable in that the eye is able to detect any error by a glance at the diagram, while the former is accompanied by no such check. A convenient check is sometimes more valuable than a process.

To state briefly in words the general method of procedure to obtain the settings, it is simply to find the radius of curvature of the desired tooth curves, place the templet odontograph on that radius, and strike the tooth curve.

The odontograph is especially adapted for this, in that all the tangents drawn to the curve of the hollow edge of the instrument are normals and radii of curvature to the convex edge. Thus FD, Fig. 4, page 5 of July No., 1876, VAN NOSTRAND'S MAGAZINE, is perpendicular to the convex edge at D, and also FD is the radius of curvature of the curve ADB at D. For this reason the odontograph may unhesitatingly be used instead of a circle for drawing a tooth curve, the proper tangent FD being brought to the circle radius; that radius being so located by construction that the point D will fall in the midst of the arc to be used. This point, for a face of a tooth, may be at about a third of the height. But, to indicate the mode of proceedure more fully, it will be desirable to take up special cases.

I. FOR APPROXIMATING TO EPICYCLOIDAL TEETH WITH CURVED FLANKS.

1st. *For ordinary Spur Gearing.*—In Fig. 1 let A and B represent a pair of pitch circles touching at C; and with ACB the line of centers. To find a face for A, and its properly mated flank belonging to B; draw any circle CD HI, with CH less than the pitch circle radius BC. Then draw a circle through D with the center at A, this circle being about one-third the height from the pitch line of A to the point of a tooth of A. From D, where these assumed circles intersect, draw a line to H, and also a line through C produced to F. These lines will be perpendicular to each other, because CDH is in a semicircle. Then find I by making HI, and CI parallel to the other two lines. Through I, draw BIF, and AEI. Then F and E are the centers of curvature respectively of the hypocycloid and epicycloid passing through D, described by rolling the circle CDH along the inside of the pitch

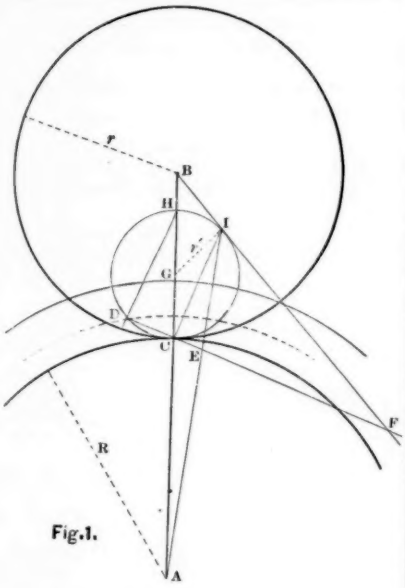


Fig. 1.

circle B, and outside the pitch circle A. Also DE is the radius of curvature of this epicycloid, and DF of the hypocycloid at D. This completes the diagram as far as required for drawing the approximate epicycloid through D for a face of A, and for drawing the approximate hypocycloid through D for the flank of B upon which the face of A, just obtained, works.

To show that DE and DF are the required radii of curvature: call R the radius of A, r the radius of B, and r' the radius of CDH. Then $CH=2r'$ and by geometry

$$CD=HI : CE :: R+2r' : R$$

or

$$\frac{CE}{CD}=\frac{R}{R+2r'}$$

But the radius of curvature of the epicycloid for A is

$$\rho=CE+CD=CD\left(\frac{R}{R+2r'}+1\right)=2CD\frac{R+r'}{R+2r'} \quad (1)$$

the same eq. as given in Rankine's *Machinery and Millwork*, p. 60.

Similarly for the radius DF for the hypocycloid for B we obtain

$$\rho'=2CD\frac{r-r'}{r-2r'}, \quad (2)$$

the same as given by Rankine and others.

We have then a very simple diagram for arriving at these radii and centers of curvature.

The diagram may be abridged a little in practice. Thus, it is only necessary to draw ACB; the Pitch circles A and B; the assumed circle G; to find D at a third the height of the face; to make HI=CD; and find the intersections E and F.

In assuming the circle G, any diameter may be chosen. If it equals CB, the flanks will be radial, and the smaller it is the more will the flanks be curved. A few trials will enable the designer to hit about right.

As regards the height of the point D, taken at a third of the face, any height would lead to very good results, but the third is found to be about the most satisfactory.

Having, now, the radii and centers of curvature, circle arcs may be drawn if considered sufficiently accurate, but the Templet Odontograph will give much better curves.

To set the odontograph, it will be only necessary to measure the length of the radii DE and DF in inches and tenths, to obtain the setting number. For instance, if DF were $2\frac{1}{2}$ inches, then $2\frac{1}{2}$ is the proper number to look out on the scale of the odontograph as indicated by the dash at the graduated edge of the instrument shown in Fig. 2. In other words, the number $2\frac{1}{2}$, as indicated in Fig. 2, is to be brought to the point D, Fig. 1, while the hollow edge of the instrument is to be brought just tangent to the line DF. This can be very conveniently done by remembering that the $2\frac{1}{2}$, for instance, is exactly the distance in inches

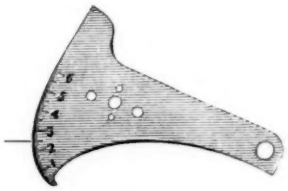


Fig. 2.

from the dash, Fig. 2, to the point of tangency in the hollow edge, as above stated. Then DF, Fig. 1, being $2\frac{1}{2}$ inches, if a sharp pencil or other point be placed at F, and while the hollow edge of instrument slides against it, we bring the $2\frac{1}{2}$ point of scale at D, we have all correct, and ready for tracing the tooth curve through D, by passing the pencil or scriber along the convex curve of the instrument.

In a similar manner proceed to trace the curve through D for the radius DE. The latter should start from the pitch line of A and will form the face curve for a tooth of A, while the former should start from the pitch line B, and will form a flank curve for B. These positions of the odontograph are shown in Fig. 3.

After once having found the true position of the odontograph for one face of

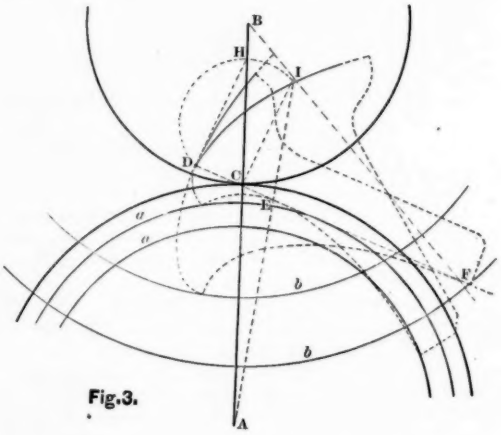


Fig.3.

A, it may be transferred to the other teeth in two ways. One way is to attach it to a radius rod so that it will swing around. But the other way will probably be preferred by most draughtsmen, and consists of simply passing the pencil around the point and heel of the instrument while in position, and then drawing circles, *aa*, concentric with the pitch line A through these points, as shown in Fig 3. Then by placing the instrument with point and heel against these circles, and in the right place for any face, that face is readily traced. The same procedure holds for concentric circles *bb*, about B, for flanks.

If it should ever be desired to trace convex flanks, it is only necessary to assume the circle G with a diameter greater than BC. In this case F falls to the other side of C.

So far, we only have the faces for the teeth of A, and flanks for B. To obtain the faces for B and flanks for A, we only have to repeat the construction with A and B interchanged. In practice, this can be done on the same diagram as that which Fig. 1 represents, but for clearness it has been omitted here. But the two diagrams are entirely independent of each other; the lines DEF differing except when the wheels are equal.

2d. *For Internal Gearing.*—For this the figure becomes somewhat modified for the reason that we now have epicycloids running upon epicycloids, and hypocycloids upon hypocycloids; instead of epicycloids upon hypocycloids as before.

Fig. 4 will indicate how to proceed. Having the pitch circles A and B, assume the circles G and G′, and find the points I and I′. Lines produced through I and I′, from A and B, will give the center points EF, and E′F′, with which the tooth curves are to be found as before. G′ may be assumed infinite, or, in other words, simply draw a tangent CD″ to the pitch lines at C. Then E′ and F′ fall at C. The points corresponding to

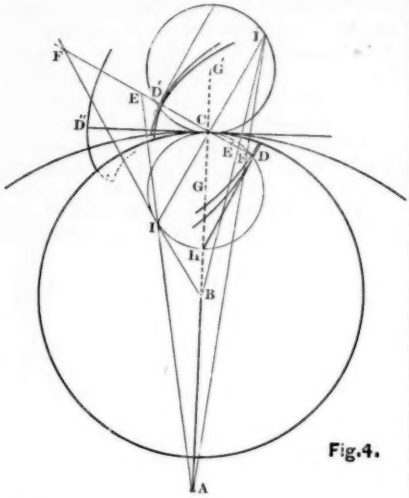


Fig.4.

D, Fig. 1, are to be found as in that figure at a third the height of face. In this figure D′F′ is made to coincide with DF for clearness of figure.

3d. *For Rack and Pinion.*—Proceed as in Fig. 4, except regard CA as infinite. Then EI is parallel to CB, and the diagram is as in Fig. 5. For this case a

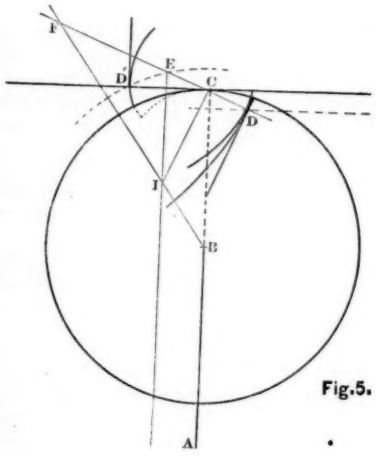


Fig.5.

good result is obtained by always assuming the circle corresponding to G′ infinite, or, simply taking CD′ on the pitch line CD′ of the rack. CD′ will then be the radius for the face of the pinion, while the flank will have an infinite radius and be straight and perpendicular to the rack pitch line.

II. FOR APPROXIMATING TO TEETH WITH STRAIGHT FLANKS.

1st. *Flanks Radial.*—This case is very simple. In Fig. 1 we have only to make CH=CB, and hence Fig. 6. The points

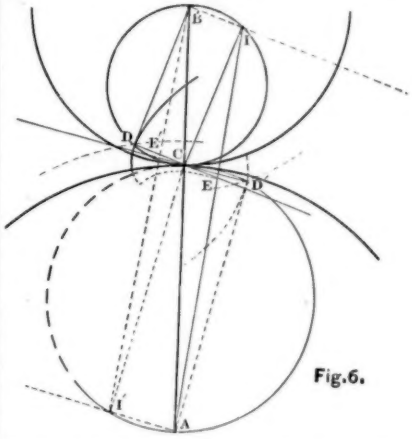


Fig.6.

F are at infinity. This would make the flanks straight; and the fact that DB and D′A are radii of the pitch line, makes the flank radial. The odontograph is here only to be used for the faces of the teeth, and its setting is made upon the radius of curvature DE, or D′E′, as already explained, by measuring the radius and using the length in inches as the setting number.

2d. *Flanks Straight and Parallel.*—This is a peculiar form of tooth, said to have been first put to practice at the Lowell machine shop. Examples of drawings of it were exhibited at the Centennial by the Mass. Institute of Technology. It is, however, simply a special case of a general solution described in this Magazine in August, 1876, p. 99, Fig. 2; and, according to Willis, due to De La Hire. It is a special case in that the flanks are straight. But the construction is simplified in avoiding the laying off of certan angles by constructing the faces by drawing numerous circles and taking their envelope. This latter so reduces the work as to give to this form of tooth its turning point of success. For a description

of this method for straight circular and other flanks, see a recent number of the *Polytechnic Review*.

From the well known fact that one tooth can be assumed, and the other, upon which it is to work, found; we readily see that any assumed straight flank will have its correct face of a tooth of the other wheel upon which to work. For our present purpose, therefore, we only seek the radius of curvature of this face by the aid of which, together with the templet odontograph, that face may be traced.

By referring to Fig. 6 or 7, we find E the correct center of curvature of the face drawn through D, because the diagram, as regards E, is the same as in Fig. 1, and the same eq. (1) applies. Also the epicycloid DJK, Fig. 7, is the one that would be generated by rolling upon the pitch circle A, the rolling circle CDB, with its tracing point D.

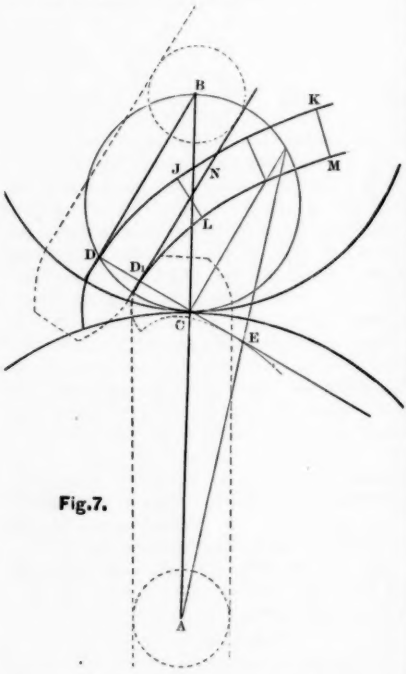


Fig.7.

Now if we draw a curve D_1LM parallel to DJK; that is, made equally distant by laying off on normals DD_1, JL, KM, etc., equal lengths, we see at once that the point E is the center of curvature of the new curve at D_1. Also it is easily seen that if DJK works correctly upon DB, as a face upon a flank; so D_1LM, parallel to DJK, will work correctly upon D_1N, parallel to DB. Again it is evident that DD_1 may be assumed at pleasure, and, of course, can be made equal half the tooth thickness. This assumption makes the two flanks of any tooth of B, absolutely straight and parallel.

Hence to draw teeth with straight and parallel flanks, proceed as in Fig. 6, except instead of D, take the point D_1 a half tooth thickness from D, and at one-third the height of a tooth face from the pitch line of A. This can probably be best done by first drawing a circle to the center B with a radius equal DD_1 or half the thickness of a tooth, and then form a right angle at D_1 with a triangle, one side against the circle, and the other at C. Thus all the flanks are tangent to the circle at B, and hence easily drawn.

The length ED_1 in inches becomes the setting number for the templet odontograph, by which a curve, closely approximating to D_1 LM, can be drawn with that instrument in the usual way.

Of course, by interchanging A and B and repeating the above construction, we get the other faces and flanks.

3d. *Flanks Straight, but Inclining at any Angle Toward, or From, Each Other.*—That this form may be realized is at once apparent from the last above, from the fact that DD_1 may be assumed of any other value than the half tooth thickness, and the circle at B drawn. Prolonged tangents to this circle will form the flanks. Also what is true of B, is true of A.

Internal gears, rack and pinions, etc., can easily be made with teeth of these forms.

III. FOR INVOLUTE GEARING.

The new method of setting can easily be applied to this form of tooth. The diagram is given in Fig. 8. A and B are the pitch lines. Draw the circle AEC and find a point E at a third of the height of a face of B. Draw the straight line ECE′, and the perpendiculars EA and E′B. Then E and E′ are centers of curvatures for involutes at C; and these can then be drawn by aid of the templet

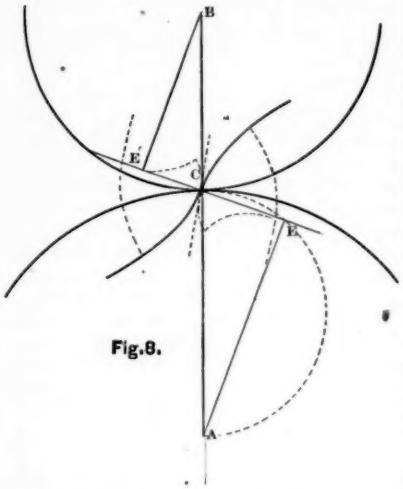


Fig.8.

odontograph with the lengths EC and E′C, as setting numbers.

Only one line ECE′ is here admissible, because the whole side of a tooth of each wheel depends upon the one line.

We might add a method of setting the odontograph which was pointed out by Professor Reuleaux, Director of the Royal Polytechnic Academy at Berlin; and printed in a German publication. It combines the graphical method with the use of the odontograph tables. It is shown in Fig. 9. A and B are the pitch

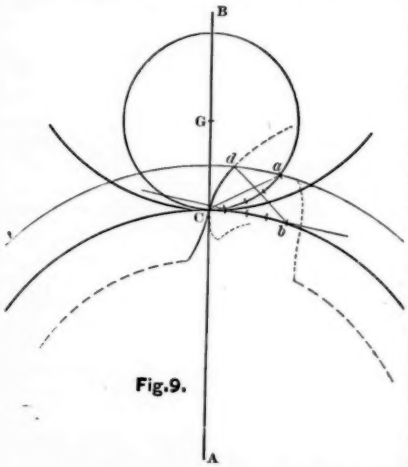


Fig.9.

circles, and G the rolling circle to describe the faces of A, and flanks of B. Draw the addendum circle for A through *d*. This cuts G, at *a*. Now with spacing dividers, step off to C on the circle G, and back equal spaces to *b* on the pitch circle A. Then take the chord *a*C, and lay off an equal length *bd*, giving the point *d*, on the addendum circle. This point will be a point in the epicycloid sought.

Now with the proper setting number found by aid of the tables, the odontograph may be brought to the tangent to the pitch line at the middle of tooth as usual in the method of setting by the tables, and with the edge of the instrument at the point *d*, trace the face curve.

The point *d* is seen to be correctly located in the true face curve from the fact that as G rolls along A, *a* will fall at *b* and *a*C will coincide with *bd*.

In this way of setting the instrument, the setting number must be obtained from the table with due regard to the particular circle G assumed. To this end the radius of B, divided by the diameter of G, becomes the "degree of flank curve" for the other wheel, mentioned in the tables and rules.

In the German publication above mentioned, one point appears to have been overlooked in that the circle on which the chord C*a* is to be taken was given as the pitch circle B, instead of rolling circle G. This may, however, have been due to an omission by the printer, or engraver.

The various methods of laying out teeth above given have been devised, as a remedy for the feeling of uncertainty in the result obtained by setting the odontograph by aid of the tables alone, as directed in the article of July, 1876. In the present methods the diagrams carry certainty with them, in the check they afford; and, it would seem, could leave but little if anything to be desired.

The teeth can, of course, be finished off by introduction of root curves, etc., in the usual way.

M. H. Tresca has been elected president of the Société des Ingénieurs Civils of Paris. M. Tresca was president in 1862, and is now elected for the third time.

TRAMWAYS.*

From "The English Mechanic."

TRAMWAYS are now a recognised mode of working urban and suburban traffic; they have made their way into public favor in the face of persistent opposition, and, instead of being removed, will probably ultimately become the only public means of conveyance on the main roads leading to and between our principal towns. Tramways are not railways, it is true, but Mr. Clark is justified in protesting against tramway-engineering being regarded as but a humble branch of the profession. On the contrary, tramways require the exercise of the highest skill that can be found, for just as railways in their infancy were often failures, so tramways have arrived at the present degree of efficiency after a series of blunders. They cost more for working expenses than railways, and they earn more per mile, but they are, of course, cheaper to construct. Such a work as Mr. Clark has placed before us was much wanted. Sooner or later steam or some other mechanical power will be employed to haul the "ponderous cars," for Mr. Clark is not alone in the opinion that the employment of horse-power in the work of starting and dragging, often on severe gradients, heavily loaded tram-cars is an element of barbarism much out of place in a civilized country. It may be true that steam-cars, or the locomotives at present devised for drawing the cars, are not all that could be desired; but it is nevertheless a fact that where they have been tried under suitable conditions they have answered the purpose very well, considering that, as yet, they stand very much in the same position that Stephenson's Rocket did to the magnificent machines that came after it. The withdrawal of the steam "dummies" (a dummy is a steam-car, the engine and boiler being carried on the same platform as the passengers) from the Market-street route in Philadelphia gave rise to the idea that steam was a failure: the fact being that the company had not enough dummies to work the traffic, and so, having to keep as many men to look after three as would suffice for twenty, and having, moreover, to run those three in conjunction with cars drawn by horses the advantages of steam were discounted. The dummies are, however, objected to, because, in summer especially, they are hot and smell badly, and it is consequently seen that the direction in which to look for a more successful application of steam to street traffic is in the shape of a locomotive, like that of Hughes or Merryweather. But in that direction we are met by two difficulties. To employ a separate motor is to lose the adhesion of the car itself; and if the engine is made heavy enough to provide sufficient adhesion to enable it to drag the car up any gradient on the road, it is probably too heavy for the permanent way, which will consequently require continual and costly repairs. The self-contained or steam-car has, therefore, one great advantage over that drawn by a locomotive—that it is best adapted for the tramways at present laid; but there is no doubt that when once Parliamentary sanction is obtained for the employment of steam or other mechanical power, without unnecessary restrictions, the demand for motors will be met by the invention of the engine required. Mr. Clark divides his work into five parts, and presents us with an enormous collection of facts carefully arranged for the guidance and instruction of the engineer and the capitalist. His first part is a history of the origin and progress of tramways, from the early timber rails employed 200 years ago to the elaborate arrangement of rails, ties, and sleepers adopted in this country and abroad. The wooden tram-rails were occasionally plated with wrought iron, but in 1767 the Coalbrook Dale Company determined to protect their oak rails with cast-iron, because the price of iron being very low, and not wishing to blow out the furnaces, they were in a difficulty as to stocking. Accordingly they cast the iron into pigs 5 feet long, 4 inches wide, and 1¼ inches thick, with three holes, through which they were fastened to the

* Tramways, their Construction and Working. By. D. K. Clark, C.E. London: Crosby Lockwood & Co.

timber rails. By this means they made the iron help to pay the interest by reducing the cost of repairs, and the pigs were there at any time when wanted. The modern tramway was first employed in the United States, where, owing to the badness of the roads and the long distances to be traversed, a rapid means of transport was the first necessity to the pursuit of business. The New York and Harlem line was opened in 1832, but did not meet with favor, and was for a time suppressed. In 1852, however, M. Loúbat, a French engineer, laid down a tramway in New York, consisting of rolled iron rails placed upon wooden sleepers. The rails had a wide groove in the upper surface, and were similar to those afterward laid down by the same engineer in Paris. Tramways had by this time become so essential to New York that the objections made to them by the proprietors of other vehicles were disregarded, and they multiplied rapidly, not only in the Empire city, which owes most of its amazingly rapid development to them, but in the principal towns of the States.

Mr. Clark speaks of the "fearless manner" in which the rails were proportioned, but they were tolerated because the tramways were of more importance than the comparatively few vehicles which traversed the streets. In 1856 a Mr. C. L. Light, an English engineer, laid an improved tramway in Boston, in which the depth of the groove was only ¾ inch, while the inner side of the rail formed a flat slope. The Philadelphia step rail was also an improvement, dispensing with a groove altogether, but having a ridge at one side against which the wheel-flanges ran; it answered its purpose well, and is still in use in that city, while a similar pattern has been adopted for New York. In fact, the step-rail may be said to be that most generally used in the United States. When introduced to England by Mr. Train it was speedily condemned, and the lines laid by him at Birkenhead and the Potteries were only saved from suppression by the substitution of flat grooved rails of the kind with which we have since become familiar. The modern practices, for there are several methods still, as it were, under trial, are fully explained in Mr. Clark's book, and the numerous woodcuts and lithographic plates render his work of great value. The present practice of tramway construction forms the second part of the book, and the many tables of cost and working expenditure which he has inserted in part three will be studied with attention by the municipal authorities and capitalists Part four introduces us to what may be termed the mechanical portion of the subject, although it is confined to a description of tramway cars. It is impossible, within the limits we can devote to a notice of this book, to give even an outline of the many details of the numerous cars which Mr. Clark describes. It must suffice to say that examples of the best constructions are fully illustrated, and that the latest improvements are noticed, down even to Eade's reversible car, which was patented in 1877. This car is swiveled centrally on the underframe, so that after the locking apparatus is unfastened, the driver can turn the car round without leaving his seat. This arrangement avoids the necessity for shifting the horses and pole, and the car is, of course, constructed with only one door and two staircases to the roof, one on each side of the platform. Mr. Clark says it is reported that the reversible car effects a saving of 30 per cent. in the horse-power required—a stud of eight horses working it as efficiently as twelve work the ordinary car. Eade's car is unusually light, weighing empty only 34 cwt, while one wheel on each axle runs loose. The alleged saving in power is, of course, due to the lightness of the car not to its reversibility. It is in use on the Salford tramways. The fifth part, Mechanical Power on Tramways, will be of most interest to the great majority of readers, for the development of the tramways system depends almost entirely on the application of mechanical power for their working. The report of the Select Committee issued recently will probably give a stimulus to the introduction of steam and compressed air motors, though they will still be hampered by restrictions which seem, to those familiar with engines, to border on the absurd. Mr. Clark in his historical sketch of the application of mechanical power to tramway cars, commences with Latta's "dummy," put on the Cincinnati Tramway in 1859. The

earlier efforts of Trevithick and others are ignored as not, strictly speaking, belonging to the subject. Mr. L. J. Todd was, however, the first engineer to bring forward any practical designs for the employment on roads of steam-propelled tramcars; and, we believe his engines were the earliest which met all the conditions imposed—viz., the absence of noise, smoke, and steam, with the possession of the power of stopping and starting quickly. About the same time Dr. Lamm experimented with an ammoniacal-gas car, and demonstrated the practicability of the invention; but the necessity for preventing all escape of the gas, together with its chemical action on iron, led Dr. Lamm to abandon for a time his ammonia engine in favor of the fireless locomotive, which consists of a strong well-clothed reservoir filled with water at a very high temperature. The fireless locomotive is running on the line about six miles in length, between New Orleans and Carrollton, the stationary steam-generator being at the latter place. The reservoir of the locomotive is filled with cold or preferably warm water, and then is connected to the Carrollton boiler, and steam of 200 pounds pressure forced in. The water is thus quickly heated and a pressure of about 180 pounds per square inch obtained. The contents of the reservoir is about 60 cubic feet, and in practice it is found to contain sufficient steam to run the car from Carrollton to New Orleans and back without reducing the pressure much below 50 pounds. The exhaust was discharged into the atmosphere making clouds of moist white vapor. Two other fireless locomotives were tried on the East New York and Canarsie Tramway, but they were not so successful as Dr. Lamm's. About this time Mr. Baxter, in America, and Mr. John Grantham, in this country, brought out steam-cars. Baxter's had an engine with compound cylinders and carried 54 passengers; and Grantham's, which was the first steam-car actually built and tried in England, had a boiler on each side of the body, in the center of its length with the engine underneath. It carried 44 passengers and worked well enough on the trial line at Brompton, but failed when tested on the line between Vauxhall Bridge and Victoria Station. It was removed to Wantage, but was unfitted for the inclines and curves of that tramway. It was subsequently altered by the advice of Mr. E. Woods, who replaced the two separated boilers by one, which was completely boxed in, and served to divide the car into portions, leaving a passage at one side communicating between the first and second class divisions. One pair of the wheels was used for driving and one wheel of the other pair ran loose, for ease in passing curves. It accommodated 60 passengers, and its estimated cost, from experience of its work on the Wantage line, was less than 4d. a mile run. Mr. Woods recommended that the Grantham car, built for the Vienna tramways, should have the boiler and engine placed at one end, while instead of the loose wheel on the undriven axle, he proposed a four wheel bogie. This car was fairly successful, but the boiler though a rapid generator, was too limited in water room, and required very skillful management. On a good road the working speed is from 10 to 12 miles per hour. In 1874 Mr. Loftus Perkins designed a tramway locomotive for a Belgian company. It was worked at a pressure of 500 pounds on the square inch, and had compound engines, the high-pressure cylinder being single-acting. The steam exhausted into an air surface condenser, consisting of a number of copper tubes. The boiler was of bent iron tubes 2¼ inches in diameter (inside) and ⅝ inch thick, tested to 2,500 pounds on the square inch. Coke was the fuel, the draught being due to the height of the chimney alone. The speed of the crank shaft was reduced by toothed gearing in the ratio of four to one, and the motion was taken off the second shaft to the wheels of coupling-rods. At the commencement of its working life this locomotive was reported to be perfect—"no smoke, no escape of steam into the atmosphere, no noise, no feeding of water during the trip, nor even, if needful, for several days." The high pressure, however, rendered it very difficult to maintain the joints, and after altering the engine, the Belgian authorities concluded to take it to pieces and sell it as old metal. Mr. Perkins has, however, recently improved his design, and Mr. Clark says at the

conclusion of an elaborate description, accompanied by an excellent lithograph, that "it is anticipated that very economical results of performance will be obtained by the use of this locomotive. The Société Métallurgique et Charbonnière of Belgium constructed a tramway locomotive in 1875, with a Brotherhood three-cylinder engine and a Bellville "inexplodable boiler," the speed being reduced by spur gear. It resembles an omnibus in appearance, and altogether is scarcely likely to become the motor of the future. Of the numerous devices that have been tried we can only allude to Francq's improved hot-water locomotive, in which the steam from the reservoir is admitted to an intermediate chamber, where it is maintained at a fixed pressure; to Todd's hot water steam-car, in which the reservoir and machinery is carried beneath the floor; to MM. Bède & Co's hot-water steam-car which has been running regularly and successfully in Belgium, and to the engines of Merryweather, Hughes, H. P. Holt, Ransom, and Baldwin, the two former of which are well known from description, already published. Most of the designs are illustrated by diagrams, and some have large lithographic plates devoted to them. It will be understood, from what we have said, that Mr. Clark's work is a perfect treasury of tramway facts, but it is even more than that, because some of his chapters are occupied with dissertations on the principles of tramway construction and working, in which points apt to be overlooked by inventors are carefully considered. Cars, he thinks, should be constructed on double bogies, or, still better, on radiating axles, and they should have a longer wheel base than is now usual. The results obtained with the Paris omnibus car, Mr. Eade's car, and Mr. Cleminson's flexible wheel-base car, point to the desirability of starting afresh with new ideas, and recasting the design of the tramcar. The production of a noiseless, vaporless, smokeless, and handy machine will not come from those who too slavishly follow the old lines; but of the present devices Mr. Clark awards the palm, as first in order, and foremost in practical performance, to the Merryweather, which in Paris and in other parts of the Continent has been doing effective service on the tramways, "causeless of annoyance or hinderance to the ordinary traffic of the streets." It is too much to hope that this work will lead to the prompt withdrawal of all vexatious restrictions on the use of mechanical power for propelling street cars; but, while it places a vast amount of practical information before the engineer, it serves to enlighten those who may ultimately have to decide whether a mechanical power tramway shall or shall not be allowed in the districts over which they have control.

COTTON POWDER OR TONITE.

From "The Engineer."

One of the marvelous applications of chemistry is the discovery of the modern explosives known as nitro-glycerine, gun-cotton, dynamite, litho-fracteur, and under other names. The late war, and especially the destruction of the two Turkish monitors, the general introduction of torpedoes and torpedo vessels, the destructive explosion at Stowmarket, the disaster, fearful in every sense, at Bremerhaven, have directed even popular attention to these extraordinary substances. Like other forces of nature, powerful servants but evil masters, these materials render very great services in many operations; and, in case we have a war, our control of the manufacture of most of them should be of the greatest importance. There is now a competitive struggle going on between the different blasting explosives in the market, and only time will tell which one will obtain the mastery. All of them evolved in the laboratories of chemical analysts, their introduction has undergone many vicissitudes; and enormous labor and sums of money have had to be spent before they could be rendered practically

useful. On the introduction of gun-cotton by Schoenbein in 1846, great expectations were at once raised, experiments on a lavish scale were carried out with it, especially by the Austrian Government; but in the course of a few years it was relegated to the laboratory shelf. About 1860, Sobrero introduced his nitro-glycerine; but Herr Nobel had to render it practical by mixing it with an earthy absorbent, producing what is now called dynamite, before it could be rendered what may be termed chemically stable and a fairly safe article for blasting purposes. Again taking up gun-cotton, Professor Abel has rendered it similar services, mainly by pulping its fibre, and by thus rendering the texture uniform, enabling it to be more thoroughly washed. The Stowmarket explosion, however, showed the necessity of using it in the wet state, as it was fortunately discovered that it could then be exploded by the use of a strong primer of dry gun cotton.

As we are all accustomed mentally to compare an explosive with ordinary gunpowder, at first sight scarcely anything is stranger than to see a quantity of matter embodying an appalling amount of explosive force harmlessly burning away like a candle. But the comparative safety attending the use of modern explosives known under the names of gun-cotton, lithofracture, tonite or cotton powder, is due to the fact that they cannot, under ordinary circumstances, be exploded without the application of a special detonator. But most of them are liable to more hidden and insiduous influences. While gunpowder only explodes by the heat generated by friction, or by the direct application of a flame or spark, dynamite, for instance, is liable to explode unexpectedly while being thawed; and the union of the nitric radicle with the glyceric elements being of a weaker character than the similar union in gun-cotton, it follows that the original nitro-glycerine of dynamite will not resist the external disruptive forces that can be applied to gun-cotton—such as accidental concussions. This has been proved theoretically by M. Berthelot, well known for his work in these departments of applied science. He found by direct experiments that the mean of the molecule of the radicles gives less heat in the formation of nitro-glycerene than is the case with gun-cotton and that the ratio of these values also gives the value of the ability of the compounds to withstand disruption. The habitual practice of the respective manufacturers in supplying detonators twice as strong for gun-cotton as for exploding dynamite is unwitting practical proof of Berthelot's discovery. Dynamite is thus probably out of the question for general use in military operations, on account of its property of freezing at a comparatively low temperature; and it is an open question whether the damp compressed gun-cotton now supplied to the British army and navy, could be exploded in a mine laid overnight in frosty weather. It has often been stated that dynamite could be thrown on a fire without causing an explosion; and this might indeed happen, but we should be sorry to be present at several such trials. Compressed gun-cotton, while wet of course, stands this fire test very well; but it can only be called wet when there is no occasion for the necessity of its standing this test at all, or when it is stored in water-tanks. Once out of such tanks the water begins to evaporate, and, in fact, some of the gun-cotton must be dried before any can be used. Hence, as in the case of thawing dynamite, dry gun-cotton has to be put in close proximity to heat, and as the substance is then highly inflammable and porous, there is liability to an explosion.

In theory there is only one element to be taken into account in estimating the blasting value of an explosive, namely, the total heat it can evolve. But in practice, on account of the very different amounts and natures of the resistance of the bodies to be acted upon, a time element is introduced. The element of space is also a not unimportant factor. For instance, if 1 pound of compressed gun-cotton and 1 pound of common gun powder be confined within a solid resisting mass of rock or metal, it will be found that the pound of compressed gun-cotton contains less than twice the energy of gunpowder. If, on the other hand, equal quantities by weight of the two be exploded freely on a common iron rail, while the gunpowder would cause a mere puff of smoke, the gun-cotton would completely shatter the rail. The

rate of explosion of compressed gun-cotton is nearly 18,000 feet per second. This extreme rapidity of explosion enables the inertia of its own mass to act as sufficient tamping, while the comparative slowness of the gunpowder explosion gives the gases full liberty to expand in the measure as they are generated.

It is a necessity inherent to the very nature of any explosive that it cannot ever be termed absolutely safe; it is only comparatively safe under certain known conditions. Thus, a great recommendation of ordinary gunpowder, when made with sulphur free from sulphurous acid, is its chemical stability; it also explodes at a high temperature, but its hardness makes it liable to ignite by friction; and, differing from the new blasting explosives, it is easily exploded by a spark. But it is the chemical stability, mainly due to the knowledge acquired during the centuries of time in which it has been manufactured, that makes it so much safer to store. The great danger from ordinary gun-cotton is this, that it is liable to chemical changes subsequent to manufacture. Such changes seem to be due to irregularities in the composition, to mechanical and chemical non-homogeneousness. This tendency to alteration is corrected by the system of grinding, boiling, and washing, which removes any free acids and organic compounds mixed with the fibre. But in spite of all this, it has still to be kept and used in the wet state, which if leading to nothing worse, is conducive to miss-fires. It is also liable to another danger. Its combustion or explosion evolves carbonic oxide, one of the most poisonous gases known, and the cause of the late accident in the Holywell district, by which one miner was suffocated and fifteen more or less injured.

There is a form of gun-cotton known as tonite, or cotton-powder, which is said to possess rather peculiar properties. It is tolerably well known as a marketable commodity, and manufactured on a large scale near Faversham. Tonite consists of finely divided or macerated gun-cotton compounded with about the same weight of nitrate of baryta. The gun-cotton itself is mainly common cotton waste steeped in nitric acid, and on the excess being forced out by a hydraulic press, or otherwise, it is left some time for digestion in vessels of clay. Necessarily while in the moist state, the fibres are macerated or disintegrated between crushing rollers. In order to give this substance what is to be complete chemical stability, it is subject to washing processes, the *rationale* of which is a secret of the maker, and which complete the manufacture of the gun-cotton. Tonite consists of this macerated gun-cotton, intimately mixed up between edge-runners, with about the same weight of nitrate of baryta. This compound is then compressed into candle-shaped cartridges, formed with a recess at one end for the reception of a fulminate of mercury detonator. In the fact of its being easily fastened to the safety fuse, it contrasts very favorably with soft, plastic, dynamite. Amongst the advantages said to result from the use of the nitrate are that it contains a great amount of oxygen in a very small volume; and that it is very ready under the detonator, while its great density makes it slow to the influence of ordinary combustion. By the employment of nitrate of baryta it is claimed that this explosive cannot merely be made much cheaper than ordinary gun-cotton, but that the same weight is about 30 per cent. stronger. It may seem incredible, but a tonite cartridge is no more liable to catch fire than a piece of soap, which it resembles; its great density causes it to burn very slowly if set fire to, and so slowly that all danger from a too violent generation of gases is obviated. While, therefore, the railways of the kingdom absolutely refuse to carry dynamite and compressed gun-cotton, they regularly take tonite on the same footing as gunpowder. The tonite cartridges are generally waterproofed. The density is such that it takes up the same space as dynamite, and two-thirds of gun-cotton. There can be no doubt that much original chemical thought has been practically applied by the officials of the Cotton Powder Company, and they claim, probably with justice, to have taken a lead in the introduction of processes for the purification of nitro-compounds—in other words, to have given them sufficient chemical stability as to obviate those dangerous internal changes subsequent to manufacture at the bottom of so many disasters.

ARTIFICIAL MARBLE.

From "The Building News."

A PROCESS of making artificial marble has been recently patented in England on behalf of Harriet G. Hosmer, of Rome, which differs from previous processes in the fact that limestone in the solid state is employed as the base instead of a mixture of plaster and cement. The limestone is worked by any suitable means to the desired form, and is then placed in a boiler furnished with a safety-valve and manometer, so that the pressure therein may be noted and controlled as may be required. The boiler is then filled with pure water at the ordinary temperature, care being taken that there is no mineral deposit introduced with the water. Care must also be taken that the water completely covers the objects placed within the boiler. The boiler is then hermetically sealed, and fire applied, and the water allowed to boil until the manometer indicates five "degrees" of atmospheric pressure if the objects are small, and six or seven degrees of pressure if the objects are large. When the heat reaches the above-mentioned point the water is allowed to cool until the pressure indicated by the manometer returns to zero. The water is then taken out of the boiler, either by means of a pump or a siphon, and the objects are removed from the boiler preparatory to being placed in the alum or colored bath. If, however, steam alone can be introduced into the boiler (always maintaining the above-mentioned degree of heat and pressure) the result attained will be the same, the action of the steam, not the presence of water, being necessary for acting on the stone. When it is desired that the objects should retain the natural color of the stone, the alum bath should consist of pure water containing five degrees of alum, as indicated by the areometer. The articles must remain in this bath at least twenty-four hours, but they may be left in the same bath for a week, or for a month even, by which time they will acquire still greater hardness. The stone will, however, have become sufficiently petrified for all ordinary purposes in twenty-four hours. If pure water be used in the boiler, according to the process first described, instead of steam, the alum bath may be effected in the boiler itself, thus avoiding the necessity of removing the objects; but it must be remembered that the application of alum is only admissible when it is intended to preserve the natural colour of the stone. In such case the alum is put in the water before the boiling commences, and the objects must remain in the boiler for 24 hours after the pressure, as indicated by the manometer returns to zero. The articles, when taken from the alum bath, may pass into the hands of the polisher if in the form of plain blocks, slabs, or flat pieces, but if they be in the form of statues, busts, vases, columns, or other ornamental works of art, they may be placed in the hands of an artist to finish, if required, as the stone does not attain its greatest hardness until it has become perfectly dry, which will require a fortnight, more or less, according to the size of the object. When it is desired to impart color to the stone the colored baths are prepared in the manner indicated below, in which the objects must be immersed, and must remain therein at least 24 hours. The colored baths must be boiling, or very nearly so, and it is better to remove the objects to be colored from the first boiler and place them in the colored liquid while they are still warm from the steam or water. There is no danger, however, of injuring the stone, even if it should be put into boiling liquid while cold, or into cold water while the articles are still heated, but the color penetrates deeper when both stone and bath are in a heated state. If it be desired to place an object a second time in the colored bath in order that it may acquire a deeper colour it should first be placed in an oven at a temperature of from 80 to 90 degrees, in which it may remain ten minutes, after which it may be immersed in the colored bath. To produce black or dark grey color take of pure water 2 litres; red wood, 300 grammes; fustic wood, 120 grammes; sulphate of iron, 10 grammes; sulphate of copper, 2½ grammes. Boil the red wood and fustic wood

for an hour and a half, then add the sulphates, and continue the boiling until all the salts are dissolved. Three or four minutes will probably be sufficient for this purpose, the solution may then be passed through a sieve, and half a tumbler of acetic tincture of iron added. Stone color or lighter grey is obtained in the same manner, with a weaker solution. In order to prepare a red coloring solution take of pure water 3 litres; Brazil wood, 330 grammes; Scotaus (*sic*), 5 grammes; cream of tartar, 1 gramme; alum, 1 gramme. Boil the mixture until all the color of the wood is extracted, and then pass the solution through the sieve in order to remove therefrom any solid matters that may be held in suspension therein. A yellow color is obtained by adding to three litres of pure water extract of yellow wood of Cuba, 20 grammes; sulphite of magnesia of alum, 10 grammes. The mixture must be boiled until complete solution of extract is effected. In order to obtain a green color dissolve in three litres of pure water extract of yellow wood of Cuba, 20 grammes; and 10 grammes of alum. Boil the ingredients as above and then add carefully (by means of a wooden spoon, and keeping at a certain distance) as many drops of acid sulphate of indigo (Saxon blue) as may be necessary to give the tone of color desired. To ascertain the depth of color pour a few drops upon white paper, or dip a piece of dry plaster of Paris in the solution. For a blue color dissolve alum, 10 grammes; acid sulphite of indigo, 20 grammes in 8 litres of water, until the desired color is obtained. As all the varied colors of aniline penetrate the stone perfectly, they may be used at pleasure. It is only necessary to dissolve the color selected in a little alcohol, which is afterwards diluted with warm water, in which alum is dissolved in the proportion of 24 grains of alum to every litre of water. The solution may be even stronger in alum; this is for colors which are insoluble in water. For such aniline colors as are soluble in water no alcohol is necessary. They may be dissolved in boiling water in which a little alum or sulphate of magnesia is introduced. Care must be taken to select only those colors which are durable. The same colors which are permanent in cloth are permanent in stone, and in general the same rules which apply to the art of dyeing cloth may be applied to the art of dyeing stone. Pavements which are colored, particularly if the color is very delicate, and if there be fear of dampness, are better laid down in cement of a light color. For the darker colors the cheaper dark cement is equally good. For the stone of which the natural color is preserved no cement is absolutely necessary unless the place in which they are to be laid is particularly damp. After the objects have been taken out of their respective baths they are allowed to dry, during which process the work may be re-touched, if necessary. When dry they are reduced to a fine surface by means of pumice stone, after which a still finer surface may be given by means of a piece of slate, or still better, of lead, after which they may be rubbed with oil. When the oil is dry the articles may be rubbed with phosphate of lime, and the lustre will be rendered perfect. The ordinary methods of polishing marble will apply to the polishing of petrified marbles prepared by the above process.

THE survey of the silver mines situated on the Comstock Lode was carried on in 1877 by Professor J. A. Church, of Lieutenant Wheeler's party. The character of the vein was carefully mapped from one thousand feet to two thousand feet deep. The heat varied from 84° Fah. in old drifts, to 116° in freshly opened workshops. The source of this heat is, it is believed with those in charge of the works, ascertained to be the decomposition of rocks under the agency of atmospheric influences. This was observed of the thick sheets of lava lying upon the vein in the upper 1,000 feet of rock. Below this, it is known to be going on for 1,500 feet further; at 2,400 feet it is nearly uniform, neither increase nor decrease is observed. The miners cut through singular bands of hot and cold rocks, a fact which seems to suggest that the origin of the local heat is the motion which is taking place is tangential and orthogonal directions in the earth's crust, as the result of its slow contraction by cooling. It is thought the lode will continue hot, but not increasingly so.

THE FLOW OF SOLIDS.*

By M. HENRI TRESCA, President of the Société des Ingénieurs Civils, Paris.

From "Engineering."

For all bodies two distinct periods are recognised—the period of perfect elasticity, which corresponds to variations of length proportional to the pressures applied; and the period of imperfect elasticity, during which the changes of dimensions, on the contrary, increase more rapidly than the pressures. If the second phase of deformation be alone considered, it is easily understood that it leads finally towards a condition in which a given force, sufficiently great, would continue to produce deformation, so to say, without limit—such as may be observed in the process of drawing lead-wire. This particular condition, in which the deformation is indefinitely augmented under the operation of this great force, constitutes in fact the geometrical definition of a third period, which has been designated by the author as the period of fluidity, and to which the greater part of his experiments on the flow of solids are related.

The period of fluidity is more extended for plastic substances; it is necessarily more restricted and may altogether disappear in the case of vitreous or brittle substances. But it is perfectly developed in the case of the clays and in that of the more malleable metals.

In his paper of 1867, the author considered the deformations of these substances by flow under certain given conditions; such as the flow of a cylindrical block through a concentric orifice, or through a lateral orifice, one of the most novel subjects of his researches; also plate-rolling, forging and punching. It was there demonstrated that in these different mechanical actions the pressure was gradually transmitted from place to place, with loss from one zone to another, in absolutely the same manner as in the flow of liquids, and with a regularity not less remarkable, but following a much more rapid law of diminution.

The pressure may be very considerable at certain points, whilst it may be nothing at all at other points, and the study of the various modes in which pressures may be transmitted constitutes in fact a new branch of investigation to which M. de Saint-Venant has given the name of plasticodynamics. It is chiefly in the operations of punching metals that this mode of transmission of pressure has been manifested, whilst the processes of forging, on their part, have afforded the means of establishing the correlation between those molecular phenomena, and the development of heat which is their direct consequence.

With respect to the formation of the jets of solid matter similar to jets of liquids, one more experiment only will be referred to, of recent date, by which the likeness is completed, and becomes absolutely illusive.

Two half discs of lead, forming portions of a cylinder, four inches in diameter, were placed in juxtaposition in the compression-press, so as to form a whole disc. Under the pressure of the piston they resolved themselves into a cylindrical jet, identical in appearance with those jets which had previously been obtained, but formed in reality of two semi-cylindrical jets in perfect contact. Their surfaces of contact bore especial traces of the successive movement of the different layers, and reproduced the exact representation, in the solid state, of a sheet of water in motion.

Punching.—Regarded as a question of kinematics, the punching of various substances, as wax, clay, plastic metals, supplies instances of absolutely identical deformations. Shortly after the paper of 1867, some nuts which had been manufactured by punching hot, in England, and which were sent to the author by the kindness of Mr. Bramwell, enabled him to remark the same effects, still better developed by the phenomena of the drawing of the fibres, so well manifested in the specimens now lying on the table.

The two punches, which act in opposite directions, enter the block of metal from opposite sides, and the piece which is left between them is diminished in

* Paper read before the Institution of Mechanical Engineers.

thickness by flowing from the center towards the circumference, until, when the two punches are moved in the same direction, the piece reduced to a minimum thickness is shorn off and discharged outside.

The phenomena which take place in this metal, softened by heat, are such as would take place in a liquid; and they lead us to expect that the deformations observed in punching lead should be produced similarly in analogous operations on the hardest of metals.

The author had already shown the inflexion and the curving of the fibres by the punching of discs of cold iron, at the works of MM. Cail & Co., and also the same phenomena in the burrs which were punched out; but he had not been able, on account of the insufficiency of his apparatus, to obtain, with iron, as much reduction of the height of the burr, as was obtained in his experiments with more plastic substances.

The section of one of these burrs, taken in a vertical plane through the axis, does not admit of any doubt of the deformations produced.

In a special memoir presented to the Academy of Sciences, on the 31st December, 1869, the author endeavoured, on the basis of an enlargement of the burr in the zone of fluidity, as it is called, just under the punch, to establish a general formula for the measure of the reduction of the height of the burr, taken into account the whole height of the burr, its diameter, and the diameter of the punch. The height L was given by the formula:

$$L = R\left(1 + \log.\frac{R}{R_1}\right)$$

in which R and R_1 represent respectively the radius of the burr, supposed to be cylindrical, and the radius of the punch.

When the punch penetrates it forces the material to spread laterally, until the moment when the solid unaltered portion below presents a less amount of resistance to shearing than is applied to the continuation of the lateral spread. This argument suffices to show that all burrs of the same section should be of the same height.

By the results of another and supplementary series of experiments, it was established that for all the different materials, subjected to the same action, the results were substantially alike, and corresponded exactly to the dimensions given by the formula.

But, at that time, the author was unable to experiment with blocks of iron sufficiently thick to embrace a range of evidence as to the reduction of the height of the burr, such as had been obtained with other materials; and it is only quite recently that the results of experiments on punching made in America have appeared, and have in a remarkable manner confirmed *à posteriori* the results of his previous investigations.

Several specimens of these punchings, very skilfully prepared by Messrs. Hoopes & Townsend, have been forwarded from the Philadelphia Exhibition, to the author. But the burrs proved a little longer than the lengths as deduced by means of the formula; the fact being that the blocks which were sent had been planed after the burrs had been punched out, to dress the faces. When the actual unplaned blocks arrived, they satisfactorily confirmed the algebraic formula.

The reduction of height seemed at first incomprehensible; and it can only be explained by the flow of a portion of the material into that of the block. It is to be remarked, too, that the lower face of the burr is convex, and the upper face is concave; with respect to the latter, the punch only crushes the material at the edge, whilst the middle of the face, notwithstanding the forced passage through the block, retains the original tool-marks.

The formula is deduced, as has been seen, from certain hypotheses on the mode in which pressures are transmitted; and though it be only a particular case of more general formulas, cited in the author's memoir on punching, it retained somewhat of an empirical character. Thanks to the researches of M. Boussinescq, in his theoretical essay on the equilibrium of pulverulent masses compared with that of solid masses, it takes its place as a rational formula, and it may therefore be accepted with complete confidence.

In one specimen only of all those which have been prepared by Messrs. Hoopes & Townsend, the pressure exerted by the flow of the metal has burst the block, and, on a close examination of the

bottom of the cavity formed by the punch, in consequence of the mode by which the pressure was transmitted, all the features of the results of the explosion of a projectile there may be found.

A few more sketches of punched blocks are added, showing precisely the contortions produced in the lines of junction by the passage of the punch.

It would be unpardonable if, on this occasion, no mention were to be made of the remarkable experiments on iron compressed when cold, the results of which have already been presented at the Vienna Exhibition, and which have until now been only received with doubt, and even with incredulity.

Can the quality of iron be really improved by cold-compression? There is no longer room for doubt as to this, in view of the recent researches of Professor Thurston, and the numerous specimens which are to be found in the collection of Messrs. Hoopes & Townsend, with the actual particulars of the forces under the action of which they were ruptured.

Speaking now only of the experiments with nuts when punched cold, Professor Thurston's tables indicate a considerable augmentation of resistance relatively to nuts of the same dimensions made of the same iron, and punched hot. The trials were made, either by applying to the rod which carried the nut pressure sufficient to strip the thread, or by introducing into the unscrewed nut a conical mandrel sufficiently loaded to split the nut. The augmentation of resistance due to cold punching may be taken at an average of 25 per cent. and this result can only be explained by supposing that there is some modification of the molecular condition of the surrounding iron, which has been subjected to compression by the flow from the mass of metal driven out by the punch.

Forging.—If it be necessary to justify the expression, flow of solids, in the case of forgings, it is only needful to prove it by the inspection of a collection of specimens of rail scalings, found on the Eastern Railway, near Epernay. Each blow is in some sort represented by the formation of a wave, and drawing-out has taken place in this fashion, by the formation of successive scales for a length of several decimetres. Deformations produced by forging only differ from this mode of displacement of the molecules in this, that they are produced for a certain purpose, and at a temperature at which the metal becomes comparatively soft.

The object of the author's early discussions on the forging of iron was to show the tendency to parallelism of all the fibres which originate in drawing out under the hammer, and which are separated from the neighboring fibres by a cementing substance derived from the incorporated cinder, which fills up all the void spaces between the fibres. This matter is frequently of a vitreous nature, very rich in oxide of iron, and when it is not burned off or pulverized at the surface of the piece when in the hands of the smith, it follows all the varieties of form to which the piece is shaped in its several parts. It has been shown, nevertheless, that the deformation may be only superficial when the action of the hammer was mild, whilst the influence of a more powerful blow, such as is practiced in industrial operations, may be felt to the core.

An oblong piece of iron may then be compared to a hank of parallel threads, which will interlock with each other when it is attempted to draw them out lengthwise, but which will separate in a much less regular manner when they are drawn in the crosswise direction, at the risk of throwing into confusion the regularity of the original arrangement; forming knots and voids which must evidently weaken the power of resistance which would be possessed by the piece under other conditions.

This effect is well exemplified by the specimen of a railing bar, in the formation of which a rectangular bar is transformed, in respect of its transverse section, into a number of rectangles and circles regularly distributed, the fibres in the circular parts losing the parallelism which is visible in the rectangular parts. This condition would certainly be critical, were it not that the central part of the enlargements was afterwards to be bored out.

The interposition of the friable silicates between the fibres, which are more properly metallic, ought to be seriously taken into consideration in this case as in many

others. At present a few of the more characteristic facts may be noticed.

From the fact that iron wire of good quality is capable of supporting, before giving way, loads much greater than ordinary iron, a manufacturer of best scrap iron tried to work it from piles exclusively composed of wire. A longitudinal section of the bars manufactured in this manner, having been oxidized, reveals the filiform structure of the bar much more clearly than any of the specimens of merchant bar iron. There is exhibited a specimen taken from an old railing at the Conservatoire which broke spontaneously in its place. Having a greater proportion of the silicates in its composition, which had been imperfectly removed in the process of forging, this specimen exactly reproduces an analogous type.

On the contrary, when the best Swedish iron is submitted to the same operation it gives but the faintest indications of longitudinal striæ, which sometimes can only be produced by taking special pains with that object.

The irons which are the most effectually purged of silicates are the best, but the expulsion of oxides formed during reheating on the surface of bars designed to be faggoted is of great importance.

The variously colored appearances that may be raised on well-polished sections, either by a deposit of copper, or by the action of an acid, or, better still, by the action of bichloride of mercury, show clearly the arrangement of the fibres, enabling us to trace, through all the deformation of a piece, the molecular displacements which, but for that demonstration, would remain undetermined.

The treatment by a very weak solution of hydrochloric acid, first employed in the Low Countries by M. de Ruth, is so effective, that by inking the surface, indented at the parts of least resistance by the action of the acid, proofs may be taken, in which the direction of the fibres is perfectly distinguishable. By the employment of chloride of mercury, the indentations and the fibres are much more neatly and delicately defined.

Without reverting to the examples given in the first paper by the author, he will now give other instances in illustration of the most ordinary results from the fibrous constitution of the metal.

On the basis of the evidence supplied by the oxidation of polished sections of iron, M. Le Chatelier sought to separate the siliceous matter which envelopes the fibres of the metal, by exposing the iron, at a red heat, to a current of chlorine. The iron is volatilized by this process, and leaves a skeleton as the residue, having the form of the original piece, composed of extremely fine filaments, and resembling, more than anything else, the residue left by a match which quietly burns without inflaming, supposing that the ash is prevented from being pulverized.

This siliceous carcase scarcely amounts in weight to a hundredth part of that of the metal, but it was associated with a certain proportion of iron, which completely disappeared in the course of the operation.

It has been stated that these silicates are friable when cold; and it appears that, with the object of diminishing the wear of bearings, the journals of shafts are sometimes hammered, in order to pulverize this interposed foreign matter, and entirely to clear it away from the rubbing surface.

Iron, by its constitution, lends itself much better to drawing out than to setting up. The difference is well exemplified in the case of a wagon axle which has been bent while cold. If it be divided down the center in a plane, the fine ribbon-like appearance is clearly brought out, and the lines are very exactly concentric. In the convex portion, it might be believed that the lines were described with compasses. In the concave portion, on the contrary, the fibres are broken and confused; at the same time, there are two fractures by compression, whilst the exterior face remains entire. Here the texture would have been altered to a still greater extent if the iron had been heated for the operation, when the metal would have been brought to a consistency like that of putty.

The deformations transversely are much better shown in a square axle four inches square, the surface of which had been subjected to a series of blows from a center-punch, at intervals of 0.4 inches. The convex portion has been extended so much that the width has been re-

duced from four inches to 3.20 inches, and the concave has, on the contrary, been spread out to a width of five and a half inches, in proportion as it was shortened in length. The simultaneousness of such deformations is well known, and they are the more pronounced as the curvature is decreased. But it is specially important to note, in this example, that the fissures which are produced are situated only in the compressed portion, whilst the portion principally submitted to extension has continued perfectly sound.

For the purpose of testing the soundness of the welds in rails the rails are frequently subjected to a series of torsional stresses in two opposite directions, which usually result in a number of longitudinal fissures of greater or less length, in the lines of separation of the component bars. But, in operating on a shaft turned out of a square bar of good iron, much more conclusive results are obtained. By the application of excessive torsional stress, the fibres are forced into relief, and the iron shaft absolutely assumes the form of a rope, in which all the exterior fibres are apparent. But the constitution of the interior of the shaft is still more remarkable. If a transverse section be taken it is easy to discover, by the agency of oxidation, the sinuous lines which correspond to the exterior helices, and of which the equation is precisely given by calculation, assuming that the angle of torsion is constant for all points of the shaft.

Supposing such a piece were to be raised to a welding heat and forged anew, it can scarcely be doubted that an iron of exceptionally great resisting power would be produced, possessing, in some degree, the best properties of metallic cables.

The ribbon-like constitution is never better manifested than in iron plates, in which it might often serve to reveal the mode of manufacture. In iron tubes, for example, which are manufactured mostly in England and in France, the regularity of the lines is such that it is only interrupted at the weld; and a means is afforded for ascertaining whether the weld has been made by simple contact, or by lapping.

The same manufacture demonstrates also the inconvenience which may attend compression. In the section of a nut for an iron tube, it is made evident by the mode of striation that the hexagonal form is produced by drawing out from a circular section, outside as well as inside. The layers are, at some points, separated towards the angles, where it was necessary that the section should be enlarged by squeezing or compression.

The object to be kept in view in the various methods of forging should be, according to the foregoing discussion, to dispose the fibres in the direction which best accords with the use to which the piece is to be applied. Mr. Haswell, director of the workshops of the Southern Railway at Vienna, has attained this object by stamping in dies piles which are suitably prepared. The author has had oxidized several of the pieces manufactured by this process for railway service; and it is clearly manifest that, though, here and there, the silicates occupy too much space, and are not regularly diffused, the fibres are, nevertheless, arranged in the most favorable direction in all parts of the section.

At several other iron works, the example of Mr. Haswell has been followed, in the manufacture of pieces by stamping, particularly at the iron works of Niederbronn. But no doubt iron of the best quality should be employed, in order to derive from this method of manufacture all the advantages which it promises.

The defects of the system are well exhibited in the section of a key forged by the stamping process from a bar of iron doubled twice over on itself.

In all operations to which iron is to be submitted it is important that the particular form of its constitution should be regarded. The excellent iron plates of Berry, which may be easily doubled, because their different layers are not sufficiently susceptible of being welded, could not, for instance, be subjected to the American mode of punching, with a punch which, being faced with a helicoid surface instead of the usual flat surface, manifestly tends to tear, at the edges of the hole, the different parts of the same layer.

Heat Developed in Forging.—The study, geometrically, of the deformations produced by forging considered under the simplest conditions, has led, from another point of view, to results which,

though they are not translated into definite figures, are, nevertheless, of some interest, whether having regard to the deformations themselves, or to the calorific phenomena by which they are accompanied.

When a square bar of iron is compressed between two horizontal flat jaws, equal and opposite to each other, the bar is flattened and elongated, and the experiments already made on the crushing of metal discs afford grounds for believing that each vertical fibre of molecules is deflected into a sinuous form, analogous to the forms produced by the crushing of a cylindrical block consisting of a pile of plates. When a prism is partially flattened the flow of the material placed under the tool is resolved into an elongation having a curved surface, of which the directrix is a logarithmic curve. The equation of the curve might be given, but it is useless to enter here into theoretical speculations. It will suffice, meantime, to mention the result, and to apply it where necessary in the course of the discussion.

In a special example of deformation obtained on a bar of lead by the blow of a hammer, the distortion very much resembles those which have been already illustrated.

If each of the four faces of the prism be divided into squares of one centimeter, or 0.40 inches wide, the comparison of the figures will show all the changes which take place on one of the sides. A small enlargement of 0.12 inches is produced on the upper face and the lower face, but this may be neglected at first. Towards the middle of the depressed portion the intermediate horizontal lines present their convexity in contrary directions towards the center-line; and the two verticals near the center vertical, have, on the contrary, their maximum separation from each other at the level of the center.

The two opposite squares, having a width of 0.12 inches show respectively two symmetrical depressions; but it is the four squares formed by the diagonals which manifest the most complicated distortions. In proportion to the depression produced, the subjacent matter is expelled both transversely and logitudinally; but the second displacement is that which it is most important to take into consideration with respect to the elongation to be produced, and it is the only displacement which can take place, when the piece is forged by stamping.

The elongation in the interior of the compressed portion being gradual, the depressed edge resulting from it necessarily presents an inclined face. It would theoretically take a logarithmic form, of which the curve would unite nearly at right angles with the original face above, which is displaced longitudinally, and, at the bottom of the depression, with the depressed portion of the same original face. This exterior side of each of the original faces of the square is thus drawn into a form analogous to that of a letter Z, of which the inclined member has been bent over in the opposite direction. The three other sides, elongated or shortened, constitute the locality of the greatest deformations; and it is to this to which the whole attention should be directed. The original lines, as well as the resulting deformations of these lines, are illustrated with absolute exactness by a figure.

It is thus shown what takes place under the action of the first blow of the hammer. The second blow should cross the first blow, when it is required to reduce the height for the whole length of the bar; and an idea may be formed of the new deformations and the restraightenings which take place, by examining the figures, in which the dividing lines are reproduced after each of three or four successive blows, one after the other. In spite of the care which was taken, the deformations are not sufficiently symmetrical, but they are characteristic enough to remove any doubt as to the distribution of the molecular action to which every part of the mass has been submitted.

The forged bar presents extended portions, and compressed portions, and the result of the work would evidently be the best possible if the vertical lines, successively deformed in two different directions, resumed a rectilinear arrangement after each deviation. The forging would then consist of a methodical series of the effects of deformation, immediately followed by the effects of a corresponding rectification.

Such effects become still more complex when the bar to be forged is not sustain-

ed between lateral guides by which all lateral extension is prevented. It is evident that new deformations will be presented under such conditions, which will modify those which have just been analyzed, and attention should be directed more particularly to the semicircular protuberances which are distributed over the length of the piece, in correspondence with each blow of the hammer.

These nipples form a kind of network produced by the forging, describing on the lateral surface a series of lozenges with curved sides, separated by the half circles already mentioned.

These undulations of the surface, which are of no importance in the geometrical operation of forging, nevertheless deserve notice, as they indicate the zones of maximum sliding, which are also the zones of the maximum development of heat; and the author has been enabled, by their indications, to connect the phenomena of forging with those of thermodynamics. It has long been known that heat is developed by the forging of a metal, and in some operations connected with the *platinage* of steel, pieces of steel subjected to blows rapidly delivered, may be raised to a dark-red heat. This phenomenon does not ordinarily take place, except in working thin sheets; and it will be shown that, in working thicker pieces, the precise situation of the greatest development of heat can be recognized.

In a forging operation which the author has had to conduct on a large scale on an alloy of iridium with platinum, a phenomenon occurred incidentally which engrossed his whole attention, bearing intimately as it did on the deformation of solid bodies. He may be permitted to refer to it, though the experiments are not yet completed; and it will be a source of great satisfaction to him to make known the first results of these experiments to an assembly of English engineers before any publication of them elsewhere.

On the 8th of June, 1874, the author simply announced the main fact at the Academy of Sciences, that when the bar of platinum, after having been forged, had cooled to a temperature below that of red heat, it happened several times that the blows of the steam-hammer which at the same time made a local depression in the bar and lengthened it, also reheated the bar in the direction of two lines inclined to each other, forming on the sides of the piece the two diagonals of the depressed part; and this reheating was such that the metal was in these lines fully restored to a red heat, so that the form of these luminous zones could be clearly distinguished. These lines of augmented heat remained luminous for some seconds, and presented the appearance of the two limbs of the letter X. Under certain conditions as many as six of these produced successively could be counted simultaneously, following one another according as the piece was lifted under the hammer so as to be gradually drawn down for a certain part of its length.

The appearance of these luminous traces can be explained beyond all doubt. They were the lines of greatest sliding, and also the zones of the greatest development of heat—a perfectly definite manifestation of the principles of thermodynamics. That the fact had not been observed before was evidently owing to this, that the conditions necessary to be combined at the same moment had not been present under such favorable circumstances. Iridised platinum requires for its deformation a large quantity of work to be expended upon it. The surface takes no scale, and is almost translucid when the metal is brought up to a red heat. The metal is but an indifferent conductor of heat, and its specific heat is low. All these are conditions which are favorable for rendering the phenomena visible in the forging of this metal, whilst it has remained unobserved with all others.

Although this explanation was what was to be expected, the author nevertheless proceeded to justify it by experiments of a more direct character, of which some account will now be given; and which constitute the chief motive, and it may be added the chief point of interest in this communication.

Given a bar of metal at the ordinary temperature, if, after having coated it with wax or with tallow on two faces, it be subjected to a single blow of the steam-hammer, the wax melts where depression is produced, and it is observed that the melted wax assumes in certain cases the form of the letter X, as

was observed in the case of the platinum bar. In other cases the limbs of the cross are curved, presenting their convex sides to each other. The heat has then been more widely disseminated, and the wax melted over the whole of the interval by which the curves are separated.

The prism which has this melted outline for base, and for height the width of the bar, represents a certain volume, and a certain weight; and if it be admitted that the whole piece has been raised to the temperature of the melted wax, the elevation of temperature represents a certain quantity of heat, or, in the ratio of the mechanical equivalent, a certain quantity of internal work which is directly exhibited by the experiment.

In comparing this work with the work done by the fall of the hammer, a coefficient of efficiency is obtained which amounts to not less than 70 per cent. This value cannot be taken as final; it depends upon the conductibility of the metal, on the stiffness of the apparatus, on the clearness of outline of the melted surface. But what the author is desirous to impress upon the meeting is that here there is a return to the first methods of Mr. Joule, and that the author's investigations of the flow of solids conduct him to certain thermodynamic demonstrations.

The following are the numerical data for some of the experiments, together with the illustrative figures:

(*See Tables on following column.*)

Name of Metal.	Work of the Ram.	Form of the Impression.	Area of Wax melt'd	Thickness of the Forging.
	kgm.		sq. ct.	cent.
Iron....	80	Rectangular	1.45	2.5
"	90	"	1.50	2.5
"	110	Wide-spreading	2.20	2.5
Copper.	60	Rectangular	1.75	2.0

Volume of the Correspondi'g Prism.	Corresponding No. of Heat-Units (Heating to 50 deg. C.).	Equivalent Work, at the Rate of 435 kgm. per Caloric.	Proportion Percentage of Total Work converted into Heat.
cu. cent.		kgm.	
3.63	0.1498	63.72	0.796
3.75	0.1547	69 79	0.731
5.50	0.2269	96.44	0.877
3.50	0.1329	56.48	0.942

In the last experiment, taking as melted the area of wax included between the hammer and the crosses, a useful effect of 94 per cent. is obtained.

Stamping.—The object of stamping is to dispose the relative displacement in given directions, in order to pass from the primitive form, supplied direct by the maker, to the definitive form which is desired to be accomplished. From this point of view, the die is a kind of channel designed to facilitate the flow of the material, and to guide in the most suitable direction or directions. When it is required to draw down by stamping a square bar of iron, each blow of the hammer causes transverse enlargement as well as elongation; and the useless enlargement is advantageously obviated if it be prevented by the presence of the sides of the canal. If it be well to employ the stamp in simply drawing down a bar, how much more indispensable is it when the variation of form is more complex? The simple idea of flow supplies material for forming a rational judgment on the successive dispositions of the stamps required for the intermediate operations; and also on the adjustment of the sections of rolls, which are but circular stamps or moulds, by means of which iron is drawn out.

That all these phenomena are but various forms of flow, of which in most cases the circumstances can be anticipated, may be shown by other experiments which will now be described.

The most characteristic of these experiments is, perhaps, the following:

Having completely effaced the reverse in relief of a piece of money, place the flat surface on a sheet of lead, and flatten the second face in the stamping press. The whole relief of this face will be produced on the face which had been reduced to flatness; and the design of this relief will even be imprinted on the lead. This effect is explained by the circumstance that each vertical thread or fibre of molecules, being separately compressed in the direction of its length, flows, when struck, with greater facility into the lead than into the other parts of the piece. The saliencies, as reproduced, are less, no doubt than in the or-

iginal relief, whilst the more delicate features are partially obliterated, but the general effect is reproduced and it is apparent that the flow takes place in the direction of the depth, which is also the direction of least resistance.

On the reverse of the sheet of lead, which has necessarily been reduced in thickness by the effect of the imprint, the image will be found repeated in a more confused manner, and it may be distinguished by a peculiar tint which indicates a well-defined geometrical transformation; the lead having flowed in a horizontal direction, as the only way of escape when its surface was depressed. This amplification or enlargement takes place in the proportion of 22 to 13, when the plate of lead was $\frac{1}{8}$ inch thick.

An entirely different effect is produced when a medal is struck. The blank piece having been placed in the matrix, the portions which are not to be raised in relief by the action of the press are reduced in thickness, for the benefit of the neighboring portions which are raised; the metal literally flowing, in radial directions, from the hollows to the reliefs by which they are surrounded.

If the medal has only an engraved face, it may be made up of several blanks of equal thickness superposed. The same mode of distribution of the molecules takes place, and is manifested by successive imprinting at each face, in which the final relief is more or less obliterated.

It is so clearly a manifestation of flow that takes place under these conditions, that if the bottom of the matrix be hollowed out at the center, then, the material which converges from the circumference exciting a pressure towards the center, the central portion of the blank is driven towards the orifice, where it forms a very regularly shaped boss; admitting of the transformation of a relief, executed on a plane, into a similar relief on a surface which has become very convex or very concave, according as the design pertains to the upper or the lower face of the blank.

To an analogous cause, the presence of scars sometimes observed on medals highly relieved, is to be attributed; these scars being produced simply by the junction, during the later strokes, of the edges of the bosses which are formed by the earlier strokes.

When the medal is relieved on both faces, if it be made up of several plates superposed, it is interesting to remark the successive developments and effacements of the images on both sides of the plates; mingling and merging in each other in a singular manner.

Rules cannot yet be formulated for the best forms of the grooves of rolls; but it may be accepted that they should be shaped in such a manner as to utilize as far as possible the natural flow of the metal in the direction of the pressures applied to it.

It has been shown that, when a bar is to be drawn out, it is best to prevent any enlargement of it laterally, and to facilitate the longitudinal flow; the die should, therefore, be carefully gauged, short, and opened out in the direction of the length.

It has been seen, also, that in stamping a disc, it may be useful to make use of centripetal compression. Each mode of action has thus its own mode of deformation of which it is necessary to know how to take advantage. The following is a very remarkable instance: Given a disc of lead 4 inches in diameter and $\frac{1}{3}$ inch thick; if it be pressed, in the stamping machine, for a diameter of $2\frac{1}{2}$ inches at the center, the thinning of this central portion is only effected by the flow of the material outwards; and this flow is exactly symmetrical, when the centering is perfect. The exterior border is developed in the form of a tulip. By such means, without the employment of a matrix, geometrical forms of a perfectly definite character may be produced, which may be useful in some cases.

This general disposition of material had been long since observed by MM. Piabert and Morin, in the course of their experiments in drawing out blocks of clay. Around the orifice of entry the clay was thrown out in the form of acanthus leaves, and the same development is to be observed in the displacements which take place when projectiles are discharged against armor plates. The metal displaced by the projectile is driven forward in flakes or strata more or less involved and dislocated, which have, nevertheless, a striking family likeness to the dispositions previously noticed.

The geometrical condition of the de-

velopment in tulipform of the plate of lead may be very simply explained. The border of the plate, which makes an effort to retain unaltered its diameter and its thickness, continues to be attached to the central portion, the gradual crushing of which throws out rings which are successively thinner and thinner. These rings have, therefore, at each instant, a given thickness, and by their succession they necessarily form a surface of revolution, which is accurately calculable, on the hypothesis, which is perfectly justifiable, that the volume is constant.

The conditions of such development may be modified by the employment of casings of various forms, but attention will be confined to the case of a concentric casing so disposed as to prevent any increase of diameter.

Eight discs of lead 1½ inches in diameter having been placed in a cylinder, a piston of 1.20 inches in diameter is placed upon the pile formed by these plates. Since the material can only escape from the compressive action by the annular space comprised between the piston and the cylinder, it ultimately assumes the form of a sort of tumbler, of which the height is extended to the length of the piston, even beyond the length of the cylinder. The thickness of the tumbler, 0.15 inches, would have been more regular if but one disc of lead, or of tin, had been employed. But the mode of distribution of the layers in the thickness of the tumbler is in itself a useful subject for consideration. The uppermost plate has been developed, almost in one piece, to the upper edge of the tumbler, being connected by a continuous supplementary part, which becomes gradually thinner until it reaches the foot of the tumbler. The other plates are also developed, in a parallel direction, supported by the sides of the cylinder, for a length which may be submitted to the same kind of calculation as that of the plates of the concentric jets. It is the same mode of deformation applied, in the present case, to an annular jet; and the complete analogy between the formulas which give expression to their relations is not one of the least remarkable facts in these transformations.

This method has for several years been adopted in industrial operations, under conditions of precision which are truly astonishing, in which a vertical and cylindrical jet, 12 inches high, is manufactured from a sheet of tin perfectly smooth and of uniform thickness. In the finest specimens of that size, the ends of the tube, which are pared after having been struck, do not show any irregularity exceeding $\frac{1}{12}$ inch in height, even though the cylindrical envelop has been suppressed for the whole height. The substance driven out in the form of a ring, the thickness of which is measured by the difference between the radius of the punch and that of the matrix, is naturally disposed to form a thin cylinder, the several elements of which slide with equal facility upon the perfectly polished surface of the punch.

A thousand examples of similar surprises may be found in industrial processes; but this instance, amongst them all, definitively sanctions the expression by which the author believes he is authorized to designate the results of his researches. The flow of solids is now recognized in science; much more will it be accepted by the members, who are witnesses every day of the processes which are based upon it, as the true expression of the best ascertained facts.

Planing.—Of the various operations which have been described above, that of punching is the only one which has had for its object the dividing of a solid body, and forming two entirely separate parts—the burr and the punched block. The block is augmented by compression of a portion of the matter which constituted the cylinder which would have been simply pushed out by the punch, supposing that the cylinder could have slipped out without giving rise to other phenomena. The burr is reduced by the same amount.

Cutting or shearing does not really take place until the moment when the burr, in consequence of lateral flow, has been reduced to its height. It has been proved that from this moment the resistance opposed to shearing is actually proportional to the area of the zone of shearing. The co-efficient of resistance applicable to this separation is no other than the co-efficient of resistance of fluidity; or what amounts to the same thing, the co-efficient of resistance to rupture; so that we are now put in possession of a cer-

tain formula, applicable equally to circular shearing by the action of the punch, and to rectilinear shearing by the shear blade or by the turning tool.

In each case one of the parts of the piece slides upon the other part, producing at the two sides in contact a drawing out of the successive layers, which are bent over in the direction of the length of the shorn surface, in thin shreds, like those produced by the punch. The separation only really takes place at the moment when these shreds are drawn to their extreme limit of tenuity.

This characteristic of the separated surfaces is met with in planing, although the principal circumstances may here be entirely different; not less remarkable, however.

The principal difference consists in this, that the chief compression takes place, not in the solid mass as before, but in the cutting which is detached by the tool, which, as it forms the exterior portion, opposes to the flow the least resistance. If the cutting be compared with the space which it occupied in the block before separation, it is easily observed that it is at the same time considerably shortened, and that, consequently, its thickness has been augmented in the inverse of the shortening.

The leading fact in planing is very well exemplified in the turning from the wheel-tyre of a locomotive comprising a cutting for the rivets. These are represented as of an elliptical section, $1\frac{1}{2}$ by $\frac{4}{10}$ inches, showing that the reduction in length affected by the action of planing was in the ratio of 10 to 28, or 0.36. This co-efficient of reduction is still much greater than it is in many other circumstances; for the thinnest cuttings, the co-efficient is occasionally as low as 0.10.

In another instance, a cutting planed off transversely from a double headed rail, the height has not been altered, but the width has been reduced nearly in the same proportion as in the first example.

Another characteristic of cuttings produced by planing is that the surface of the cutting which rises from contact with the cutting-tool is always smooth, and is developed geometrically. That surface, in fact, is moulded on the tool during the process of deformation, and slides upon it in such a manner as to roll itself up in the form of a cone or of a cylinder. At this moment, above all others, the plasticity of the metal is brought into play; and if the original form of the cutting should interpose too serious obstacles to this development, it tears or splits according to the direction of the generating surfaces of contact, still responding to the geometrical condition first referred to. It is well to avoid such rents as much as possible, for evidently they cannot be produced without the expenditure of additional power. Such loss of power must take place, especially where it is required to reduce a curved surface at one cut, of great breadth. An example of such fissures is shown on about a third of the width of another cutting from a tyre; but those of the opposite edge are attributable really to a greater reduction of the length of the thinner edge in the process of planing.

The other face of the cuttings is always rugged and wrinkled with fissures or with transverse ridges, of very variable aspect, according as the metal is more ductile and the cutting is thicker. For the greater thicknesses both iron and steel present on that surface a multitude of inclined ridges partly covering one another; and of which the incline is still better defined where complete separation has been produced.

These scales have been drawn just as they appear under the microscope, on a cutting of Bessemer steel. Nothing can show better than their general inclination the sliding that may be produced in planing, in consequence of the compression which is produced in front of the tool before the cutting is completely detached from the block.

In the greater number of cases the turning when long enough winds up into a helicoidal form, as may be seen on the cutting, of which the rugged face has just been shown.

The inclination of the spirals depends upon that of the cutting edge of the tool, and their diameter upon the thickness of the cutting; the diameter diminishing with the percentage of reduction. It is thus that, in turning in the lathe a piece which is very slightly eccentric, the result is a number of parts of which the diameters are alternately greater

and less. The demonstration afforded by this single specimen is quite complete.

Without seeking to draw any conclusions from the study of these deformations with respect to the best form of tools for each of them, it follows clearly from the foregoing discussion that the work required for any cutting action whatever is expended in friction and in deformation by compression. The work of friction should augment with the number of cuts, and as the shortening is greater for the finer cuts the molecular work expended should be greater. It follows, therefore, that it it is most advantageous to make deep cuts, but, of course, this mode of action demands more powerful tools and better foundations. It is in this direction, it appears, that the most recent progress in the manufacture of tools has been effected.

The different modes of cutting, rectilinear or circular, are applicable chiefly to flat surfaces and to cylindrical surfaces.

Flat surfaces are cut in the planing machine or in the lathe, and under most circumstances the two kinds of cuttings are almost identical in appearance—that of a cylinder formed of spirals more or less close, sometimes even in juxtaposition; but for this combination, it is necessary that the two edges of the cutting should have been equally reduced, that is, that they should be of the same thickness. If it were otherwise the spirals would become conical; and such of these as appear to be most characteristic will now be described.

The cutting obtained in mortising, by means of a straight tool, is absolutely cylindrical.

When the tool cuts out, in this manner, a rectangular groove, the material is compressed without any lateral deviation. If the cutting is of great thickness, it is triangular, and the smooth surface is formed by the combination of the three faces at which the separation takes place, the direction in which crumpling takes place being the same as in all ordinary cuttings. The triangular form is the result of the compression being greater toward the middle line.

To aid in forming an opinion on this point two blocks were placed side by side, which were planed at the same time, in the line of junction of the pieces. Two distinct horns were formed, which parted symmetrically from one another; each half-cutting following the law of shortening by which it was bound to assume a form concave towards the side which was held by its attachment to the block.

Having made a similar experiment in lead, the parallel and equidistant lines that were drawn upon the block before it was cut could be traced on the cutting, and they afforded the means of measuring exactly the average percentage of reduction, and the mode of contortion of these transverse lines, which assumed successively the same inclinations as they lay one upon another at intervals, of which the percentage of reduction varied from 0.10 to 0.30.

The cuttings from a lathe, when they were produced from an annular groove, by means of a straight tool, assumed exactly the same forms. For example, a cutting from a groove in what is called the Swedish piston is a continuous ribbon rolled up as on a bobbin, with the greatest regularity, and of great length, without a rent.

When turnings take the form of a helix, the small lateral displacement of the piece is not large enough to give to the ribbon a different character to that from a planing machine, when, for instance, it is required to turn a shaft to a uniform diameter, and it is then easy, with good metal, to produce cuttings of great length. But, when it is required to turn the end of the shaft or of any cylinder whatever, the cutting follows a special course. If the tool be large in proportion to the diameter of the rings or circles on which it is acting, the difference of diameter between the two edges of the cutting makes itself felt in the cutting, which assumes the form of a helicoidal surface, with inclined generating lines, of which the directrices are two helices of the same pitch but of different diameters. This universal geometrical character, moreover, is manifested in special ways according to the width of the ribbon and the interior diameter of the ring. In this way three horns may be obtained, encased one in the other, if the cutting edge of the tool be radial. Successive spirals foul each other when the direction of the cutting edge is a little inclined. The inner helix

is replaced by a straight edge when the tool cuts right to the center of the face.

Notwithstanding these differences of detail, the same rules prevail: a greater or less reduction or shortening, according to the thickness of the cutting; a less reduction of length at the thicker edge of the cutting; a smooth surface of separation, which always forms a developable surface; a rugged reverse face ridged as if waves of metal had been successively projected there; in fact, all the circumstances of a transverse flow of material—setting apart the secondary circumstances, of transformation of the prism of metal from which the cutting is produced by augmentation of thickness and corresponding reduction of length.

The author endeavored to represent, by a diagram, the triangular cutting which would be formed by planing from the edge of a block of metal a square prism, by means of a tool having two cutting edges, and of which the flat front is itself placed symmetrically. The effect of the diagram, constructed on the assumption of a percentage of 0.30, is exactly reproduced by the model in relief. In agreement with the foregoing discussion and with the facts, it may be observed how the prism which is on the point of being separated from the block swells up by compression, commencing at a certain zone of fluidity, of limited length, in advance of the tool; and how, when this compression has arrived geometrically at the maximum which could be sustained by the material, the cutting is detached from the mass to be subjected to the action of the face of the tool, upon which it slides, and which forces it to assume its ultimate form.

Considerable as these modifications may appear, they are absolutely in accordance with the facts. They have been produced by the author, on lead as well as on the hard metals, under conditions which were exactly proportional to those which are represented by the model.

The finest specimens of this triangular transformation of cuttings that have come under the author's observation, are produced by a mortising tool. They are not less than $\frac{6}{10}$ inches thick, and the rolling up of the metal could only be effected with the accompaniment of deep fissures in the lateral edges. The upper edge, on the contrary, is much more minutely serrated, one of the lateral faces is plaited for its whole length, evidence of the compression of the material; whilst the other face, with its oblique fissures, shows still better the sliding by means of which the compression takes effect.

There is a still smaller cutting which presents exactly the same characteristics.

It is the author's opinion, that for the construction of the best machine tools, with the most suitable thickness of cuts, the minute examination of the cuttings is of the greatest importance; and that by the same means, the surest evidence may be derived with respect to the qualities and homogeneity of the metal.

Time does not permit of more than a passing reference to certain deformations which recall to mind, with a surprising degree of exactness, the constitution of certain rocks, with their dislocations. A few experiments of this kind were made by the author in conjunction with M. Daubrée, from which the latter gentleman quite recently derived an explanation of a number of geological phenomena. The results of these inquiries would no doubt possess some interest for the members, but the author was desirous chiefly to lay before them such results of his investigations as followed in natural sequence upon the substance of the communication already made in 1867.

The idea of the flow of solids is, of all the modes of regarding their deformation, perhaps the one which most truly interprets all the phenomena of molecular mechanics, and of the internal constitution of bodies, which underlie the various industrial operations.

Mr. Samuel Sharpe has promised to give £500 towards the building of the North Wing of University College, London, so soon as the Council are prepared to begin the work. It is expected that this liberal donation, together with others which have been received, will enable the building to be very shortly commenced. A sum of £50,000 in all will, however, be required to complete the extensions which are immediately contemplated.

THE ACTION OF RAILWAY BRAKES.

From "The Engineer."

On Monday morning Captain Douglas Galton and Mr. Westinghouse resumed their inquiry into the action of railway brakes, which had been interrupted for a short time to enable certain alterations to be made in the construction of the recording apparatus in the experimental van. It will be remembered that the inquiry began on May 27th, and we illustrated the experimental van and commented on the results obtained in our impressions for May 31st and June 7th and 28th. All the alterations since made in the van refer to matters of detail, their effect being that the diagrams given by the recording apparatus are clearer and more perfectly trustworthy than before. Two ends of two carrying springs have been attached to levers which act on a water-pressure diaphragm, and by means of a Richards indicator, record the action of these springs. The system of scaling the diagrams has also been modified, but with these exceptions, what we have already said in the way of description will apply to all that follows. It may be worth while for the sake of rendering matters clear, however, to explain that six indicators are used to record—(1) The angular or tangential strain on the brake blocks; (2) the motion of the carrying springs of the van; (3) the force applying the blocks to the wheels; (4) the pull on the draw-bar of the van; (5) the speed of the van, the motion of the indicator being derived from the leading wheels to which only the brake is applied; while (6) is a somewhat similar indicator driven by a belt from the unbraked wheels. There are, besides, two Stroudley speed indicators in the van, employed to check the accuracy of the Westinghouse instruments just named.

On Monday morning the van drawn by the "Grosvenor" left Brighton station and ran to Hastings and back, several experiments being made on the road. Unfortunately, however, a portion of the brake rigging gave way during the experiments, and brought them to a close. On Tuesday morning, with new and stronger rigging, the experiments were resumed, and continued on Wednesday. We may be excused for not going minutely into the investigation of the results obtained, when we state that on the first day alone more than 120 diagrams were obtained, which will have to be compared and arranged and measured before definite results can be made public. This is a work of some time. We may, however, with advantage, indicate the nature of such phenomena as appear most worthy of attention.

The first point claiming attention is the failure of the brake rigging. This consists of a Y-shaped frame, the two limbs of the Y being welded to a stout transverse rod, the ends of which are prolonged beyond the limbs of the Y far enough to pass through the brake shoes. The single leg of the Y is connected by a system of levers with the piston rod of the air cylinder, and when the brake is applied the whole Y frame is put in tension, with the exception of the transverse bar, which is in compression. The diagonal bars or limbs of the Y are of $\frac{7}{8}$ in. round iron; the transverse bar is of $1\frac{1}{8}$ in. round iron. This bar gave way by bending in the middle on Monday. It was replaced by a much stronger rigging on Tuesday. The strain put on each brake block is precisely 100 times the pressure per square inch in the air cylinder when the brake is applied. This cylinder is 8 in. diameter, and the piston is consequently 50 square inches in area. Now the highest air pressure used during the trials was 95 lbs. on the square inch in the brake cylinder. This drove each block against the wheel rim with a force of 9,500 lbs., and under the strain thus brought to bear on the tackle, the horizontal extension rod gave way, as we have said, by bending. But this, like all the similar tackle used by Mr. Stroudley, had been tested in the shops with a pressure of 120 lbs. on the square inch, or 12,000 lbs. on each shoe, and had withstood the strain perfectly. The lesson to be drawn is that unless all the conditions under which any member of a machine has to operate are taken into account, the results of tests of endurance cannot be regarded as trustworthy. In the shop

the brake rigging while under strain was not subjected to any violent jarring action ; on the road the vibration set up in the metal was active, and promoted a rearrangement of the molecules of the bar. Bearing this in consideration, it is by no means to be regretted that the rigging gave way. The experience obtained is worth a good deal, and admits of very extended application. It illustrates the prudence of Lloyd's rule that when chains are being tested by tension they should also be struck sharply with a hammer; and it throws some light on certain so-called mysterious failures of structures to do the duty expected of them, and performed by them when originally tried in the maker's yard. We may here add that tackle of the kind which gave way has hitherto been found quite strong enough in regular practice.

The results obtained when the brake was applied under varying conditions, were exceedingly curious. We have already explained that when a wheel skids two things take place—(1) The angular strain on the brake shoes is enormously augmented for a moment; and (2) it then sinks to much less than it is when the wheel is revolving with the shoes pressed hard against it. In other words, broadly speaking, it would seem that the resistance to forward motion offered by a wheel skidding on a rail, may be much less than half that offered by the same wheel while still revolving at full speed, the brakes being in action. This fact was brought out very prominently on Monday and Tuesday. To test the point in another way, a few special experiments were made. Matters are now so arranged in the van that the pressure in the brake cylinder can be determined with the greatest nicety. In the twenty-second experiment the speed of the van being forty miles an hour, the wheels could not be skidded with a pressure of 60 lbs., or 6,000 lbs. on each brake block. But in the twenty-third experiment, although the speed was forty-two miles an hour, the wheels skidded. The speed remaining about the same, the pressure was gradually reduced, but the wheels would not begin to revolve again until it fell to 7 lbs. on the square inch. From this about 2 lbs. must be deducted for the pressure required to overcome the resistance of the spring which takes the brake off, leaving a net pressure of 5 lbs. In other words, although 6,000 lbs. on each block, or 24,000 lbs. for the pair of wheels was required to skid them, 2,000 lbs., or one-twelfth of the amount, sufficed to keep them skidded. It must not be supposed, however, that this represented the diminution of resistance of a skidded as compared to an unskidded pair of wheels; on the contrary, the draw-bar diagram shows that the resistance of the skidded was somewhere about one-third, instead of being only one-twelfth that of the unskidded but braked wheels. The blocks used in this case were of cast iron, 12 in. long. Those used on Tuesday were also of cast iron, but 16 in. long. With these last, in one experiment a pressure of 70 lbs. to the square inch was required to skid the wheels, but only 6 lbs. sufficed to keep them skidded. At a velocity of four miles an hour skidding was produced by a pressure of but 40 lbs. At high velocities, such as fifty to sixty miles an hour, a pressure of less than 90 lbs. would not produce skidding. It is worth notice that, no matter what the speed of the train, a pressure of 6 lbs. to 8 lbs. kept the wheels from revolving. This appears to demolish the theory that at high velocities the coefficient of friction between wheel and rail is less than at low velocities. If this theory were correct, then when the train was running slowly a much greater pressure would be needed to keep the wheels from turning than would suffice at high speeds; but so far as the inquiry has as yet proceeded, not a scrap of direct evidence to this effect has been obtained.

There is but one way of explaining the various anomalies presented by the results of these experiments. They are in a very large proportion due to the inertia and momentum of the wheels. To elucidate this point a little, we give the following figures:—The weight of the brake van is 8 tons 2 cwt. 2 qr., or, with fourteen passengers, nearly 20,400 lbs. These figures are not precisely accurate, but near enough for our purpose at present. About one-half this weight was on the braked wheels, which invariably went first. When the brakes were applied, the springs deflected $\frac{3}{8}$ in., showing an augmentation in weight, the precise amount of which has not yet been calculated, and which was due to

causes which are too obvious to need explanation. We shall assume that the load under these conditions on the braked wheels was 11,000 lbs.; but in order to stop these wheels from revolving at thirty miles an hour, or 44 ft. per second, a pressure of 60 lbs. was required. This represents 6,000 lbs. on each brake block, or 24,000 lbs. in all; but the wheels pressed on the rail with a force of 11,000 lbs., or but eleven-twenty-fourths of the force with which the brakes were applied to the wheels. If the matter ended here, we should be justified in assuming that the coefficient of friction between wheel and rail was more than twice as great as the coefficient of friction between wheel and brake block. But the wheels when once skidded could be kept skidded apparently at any speed, slow or fast, by forcing the brake blocks against them with a force of 6,000 pounds only, or less than half the insistant weight; consequently on this basis we would have reason to assume that the co-efficient of friction between wheel and blocks was much greater than that between wheel and rail. These two assumptions are contradictory, incompatible, and yet each is justified by the experiments. Both assumptions are, however, vitiated by neglecting the mass of the wheel. Before the wheel can be stopped the work stored in it must be taken out of it. Let us represent this by x, and the resistance proper to the co-efficient of friction between wheel and rail by y. Then the duty to be performed by the brake in stopping the revolution of the wheel must equal $x+y$. Again, to put the wheel in motion after it has stopped, y must reproduce x. Let the resistance due to the co-efficient of friction between the wheel and block be represented by z. Then y must equal $x+z$, or the wheels will not begin to revolve with the brake on. We have here purposely omitted all reference to the important part played by time in this matter, as it will suffice for our present purpose to call attention clearly to the fact that momentum and inertia must be taken into consideration. To show how important a part both play in the matter, it will be enough to say that the revolving mass of each wheel of the van is as nearly as may be equal to 450 pounds moving at the speed of the train. Thus at thirty miles an hour, or 44 feet per second, the *vis viva* of each wheel is not less than 13,500 foot-pounds, and to stop such a wheel in one second would require a tangential force of 950 pounds; or assuming the co-efficient of friction between block and tire to be 0.1, then a single block would have to be pressed against the wheel with a force of 9,500 pounds, and this, be it observed, without taking any account of the friction between rail and wheel tending to keep the latter in motion. In like manner, if the speed be sixty miles an hour, or 88 feet per second, then the *vis viva* of the wheel will be nearly 54,000 foot-pounds or 24 foot-tons; and to stop such a wheel in one second, or 88 feet, would require a force of, in round numbers, 6,000 pounds, or a brake-block pressure of 60,000 pounds. It is hardly necessary to say that no brake exists which will produce skidding under such conditions in one second; and although apparently skidding does take place suddenly and with a jerk, yet it is certain that nothing like instantaneous action ever occurs. Again, when the wheel has been skidded, a force of 6,000 pounds would have to be applied to its circumference to cause it to resume motion at the rate of 88 feet per second within a distance of 88 feet; and it was abundantly proved by observation in the van on Monday and Tuesday, that if the pressure upon the brake is taken off altogether, the wheels will continue to skid for some moments, and that they resume their velocity slowly. It is well known, indeed to engine drivers that tender wheels obstinately refuse to revolve when skidded at high speeds for a quite preceptable time after the brake has been taken off.

It will be seen, then, that the task which Captain Galton has before him is no light one. Certain conclusions, having a direct practical bearing, can be drawn easily enough; but neither Captain Galton nor Mr. Westinghouse is likely to be satisfied with this. The London & Brighton Railway Company have, with the utmost liberality, placed unexampled facilities for making experiments at the disposal of Captain Galton and Mr. Westinghouse, and the latter gentleman has prepared an apparatus which will deal with any brake, air or vacuum. Facts are being obtain-

ed by the hundred, and it rests with Captain Galton to reduce these facts to a condition which will render them extremely valuable to the man of pure science, as well as to the engineer. Nothing, however, can be learned concerning the laws of friction unless the influence of the *vis viva* and inertia of the revolving wheels is carefully calculated for every experiment.

THE RIVER THAMES.

From "Engineering."

The Thames Conservancy and the Metropolitan Board of Works have, during the last twelve months, been placed in diametrical opposition in regard to their views of the cause of the pollution of the Thames, and each Board has published a report casting the blame on the other. These reports have been criticised by engineers, chemists, and others, and the simple result has been that the public have been left in a fog of Egyptian darkness as to whom is due the fact that about 20 miles of the river is rapidly approaching a state equal to, if not physiologically worse, than that which we observed in 1848-49 (cholera years) and in 1855-56, when the Thames was literally no better than a foul stinking ditch. It was from this latter circumstance—the abomination of sanitary desolation—that the main drainage scheme had its origin, and we regret to add in some senses its failure, so far as recent experience goes.

Again, the present year has afforded a repetition of evils that are periodic. For several years past the summer temperature has been comparatively low. During the last month it has been literally tropical, ranging from 75 deg. to 85 deg. Fahr. in the shade. Hence, as we shall presently show, the Thames now presents appearances that cannot be regarded without serious apprehension. If our conclusions be true the condition of the river is at least serious. Of this our readers may, without any pretension to engineering, chemical, or other professional knowledge, easily judge for themselves, and to assist them in so doing the following brief account of the observations, experiments, &c., that have been made, and the mode of conducting them, may be of advantage.

Our observations for the present year were commenced on the 13th of April. On that day the Thames from London Bridge to North Woolwich presented very much the appearance of a farmyard pond. Between Blackwall and Woolwich, the amount of confervoid matter, floating in the river, was so great that its green color could scarcely escape the attention of any one having occasion to pass down the stream. This color of course indicated the presence of an immense amount of vegetable germs in suspension. Subsequently it became evident that the river was loaded with these organisms, and on July 22, when the last of these observations were taken, the water at ebb, from Blackwall to the south shore upward of Purfleet, presented a color of a dark olive-green, with a "sweet" fetid smell common on all the marshes of the Thames and Lea, at the time the weeds, &c., decay, especially during a warm August and September.

As a rule during the three months above mentioned, samples were gathered from Westminster to North Woolwich, and occasionally to Gravesend, as the tide ebbed, so that the end of the low water could be reached at the last station, below London Bridge. None were taken at an interval less than three or four days after a rainfall, it being desirable that the river should be seen in its normal state. Here it may be remarked, that a heavy rainfall, as on June 23rd, entirely destroys what we may call normality of the stream, owing to the large amount of oxygen brought into the river in solution. From neglect of this precaution has arisen the absurd idea that sewage, running for a few miles, becomes oxidised *under all circumstances*. It may, after a heavy rainfall, for reasons already assigned. We have known for example the Leam, which runs through

Leamington, and shortly below joins the Avon, to be wonderfully improved after a rainfall, which increased the sewage to 1,500,000 gallons per day from 450,000 gallons, the latter quantity being at the time we refer to about the daily average. These and other sources of error were carefully avoided in our examination.

Our space will not permit us to give more than a general summary of the various observations made during this period of three months, but those made on July 22nd may be taken as a normal type. At 9 A.M. to 10 A.M. the river presented an appearance of a dark olive tint mixed with brown, between London Bridge and Blackwall. Between Greenwich and Blackwall there were frequent issues of suspended matter, apparently from the escape of gas from the bed of the river, which produced circular areas of increased suspended matters, so dense as to completely hide from observation the bottom of a glass 3 inches below the surface. Beyond Blackwall to Barking the smell of the water was of that peculiar decomposed vegetable character already alluded to, varied by the stench of nitrous acid and glue or manure preparations from the north bank. This was so offensive as to stir up the attention of some children, who adopted the time-honored plan of keeping the smell from their noses. The wind was N.N.E. At the Crossness outfall of the South London sewage, there was a considerable deposit of sewage matter on the bank, and on the upper part of the bank the green deposit showed signs of vegetable matter arising from the mixture of sea and fresh water.

At this point and eastwards the water in mid-channel was a vegetable green color, with a strong bilge-water smell. A mile below, the stench of some works, dealing with boiling animal matter, was most offensive. A little further below and near Price's wharf was a long sewage deposit; the same occurred near, but west of Erith. Below Erith the water became worse in color in mid-channel, with deposit of sewage matter on the south shore, especially in hollows. At Purfleet the river presented an appearance very commonly to be seen at Dumbarton on the Clyde, where sewage and sea water freely mix. The south shore near Greenhithe presented sewage deposit. Here it may be remarked that a specimen of water taken from mid-channel was perfectly free from sea-salt taste, a fact indicating that the sewage, &c., had, with the ebbing tide, traveled so far on its journey *towards the sea*, but, as we shall see, *not into it*.

At the turn of the tide at Gravesend, about noon, as indicated by a small boat presenting its stem eastwards, samples were taken of the surface water. These could only be compared, as regards suspended matter, with the worst specimens of sewage that might be drawn on ordinary occasions from London sewers. When shaken the suspended matter oscillated in the glass vessel, as if immersed in a viscid fluid, showing signs of the presence of sewage that could not be mistaken by an experienced eye. As the larger vessels (200 tons and upwards) turned stem to sea, fresh samples were taken from shore to mid-channel, with the same result. The water was brackish to the taste, indicating that the outward flow of the sewage to the sea had been arrested, In other words *the metropolitan sewage was being driven back to London*, with the addition of sea-water, which of course makes bad worse.

Here, by way of parenthesis, we may remark (as we have already frequently done) on the danger of mixing sewage with sea-water. We have, in previous volumes, drawn attention to the experiment of Professor Daniell on the effects of mixing land drainage water with sea-water on the coast of Africa, off the Niger, &c., particulars of which will be found in the *Philosophical Magazine* of (we believe) 1840-41. But our readers need not trouble to refer to those works. A walk from Rosherville to a mile beyond Gravesend, or near Hastings, Ryde, Southampton, &c., at places where the sewage runs over the low-water shore, will give sufficient evidence as to the danger that may arise from the mixture of sea-water and sewage. The sulphates of the one and the vegetable and animal matter of the other undergo mutual decomposition, produce sulphuretted hydrogen and air poison. During the next two months many thousands of persons will visit three or four watering-places on the Thames thus situated. One of the most favorite of these resorts has the reputation of possessing about three

acres of cesspools in close proximity to the sea—we mention no names. A word to the wise should be sufficient.

But to resume the thread of our observations. During the last three months samples were taken of the deposit left at low water by the sewage between Westminster Bridge and about two miles below Gravesend. Some singular facts were thus presented. Below Gravesend the mud presents, when wet, a brown appearance, turning to a blue or greyish tint when dry. On analysis, this mud seems to be the product of a gradual and natural lime process of treating sewage. In other words, the bicarbonate of lime held in solution seems to have precipitated portions of the organic matter. Where clay is the most prevalent material of the banks, the precipitate is analogous to the so-called native guano, produced by the A B C process. Another singular fact is that the precipitates have corresponding appearances when wet. The clay precipitate has a peculiar reflective surface, while the lime precipitate has a dull heavy surface, having no reflective power. It is very possible that the Thames possesses, by the varying constituents of its banks and bed, a self-purifying power, but far from equal to the requirements which four million people insist on its performing. But where neither clay nor lime present themselves, no such result can exist, and, consequently, between, say Poplar and Westminster Bridge, the sewage deposit wherever it exists, remains only to decompose, and therefore to poison the air.

The effect of the in-coming tide is remarkable. Taking the date of July 22, the sea-water had reached Crossness at about 6 P.M. Its freshness remained unimpaired up to that point, the sea tint being remarkably evident. But, above Crossness, the freshness was lost. The olive-green tint of the morning's observations was apparent, together with the smell of bilge water. Off Blackwall, the Thames was of a brownish-yellow tint, and at London Bridge at the moment of high-water it was evident that the comparatively stagnant lake, that had been oscillating to and fro, was still as bad as it was ten or twelve hours previously, and the same observation held good as far as Hungerford.

Although we have chosen a special date, because no possible intervening cause could have disadvantageously influenced the observations above related, it must be distinctly understood that precisely similar circumstances occurred during three months, and we may add to some extent for the last three or four past years. We feel therefore compelled to the belief that the conditions of the Thames (within the limits assigned) are as follows:

1. That the metropolitan sewage area of the Thames may be considered as bounded east at a little below Gravesend (perhaps at Sea Reach) with a wall of sea-water, and on the west, at a little above Battersea, by a wall of fresh water.

2. That while neither of the boundaries are exact, they furnish two different results. The sewage may pass, and no doubt does pass far beyond Battersea, but is then diluted with fresh water from the Upper Thames, despite sewage contamination from riparian towns, &c., such as Richmond, Kingston, Isleworth and the like. On the other hand, the eastern boundary supplies, by a flood tide, sea-water which by under currents runs perhaps beyond London Bridge.

3. That for all practical purposes, the sewage cast into the Thames at Barking and Crossness may be considered as located between such boundaries oscillating with the tide; that, meanwhile, in hot weather (80 deg. Fahr. atmospheric temperature) it fosters the growth of sewage fungus, confervoid matter, &c., to which it acts as a manure.

4. That there is a natural process of defecation going on, partly by rainfall, the action of lime and clay, as already pointed out, and the disturbing action of steam and other vessels. But, on the other hand, the fæcal and other matter cast from these vessels into the river may, to a large extent, add to the pollution of this stream.

5. It would appear that whatever endeavors are made at Barking and Crossness to retain suspended matter by the settling tanks, such exertions are practically futile, so far as the physiological conditions of the river are concerned. It is impossible, in the few hours during which settling can take place, that more than a small portion of the suspended

matter can be removed. Referring to experiments made at Leeds it was found that, after a few days, entire settlement of suspended matter was not effected in glass vessels that were never disturbed. But, if we take into account the rush of new sewage into a tank hourly, changes of temperature and a variety of other concomitant circumstances, too numerous to mention, any "settlement" at either Barking or Crossness is simply nominal.

The present state of the Thames has been made the subject of investigation during the last few weeks by Mr. Buckland, with special relation to the interest of the fishermen, and at a lecture that gentleman lately gave, the results of his investigation showed that the loss in a pecuniary point of view to London is very heavy. Some conversations that we have recently had with old fishermen residing at and below Gravesend, lead to the same conclusion. As early as the 12 Richard II a statute was passed enjoining the mayors of boroughs to make proclamations against throwing filth or rubbish into rivers. No communication between the cesspools of the houses and the sewers of the streets was permitted until 1847, and now we find the Thames converted into a kind of running cesspool, in that portion of the metropolis which contains most of its wealth and intelligence.

As we fully anticipated, the Rivers Pollution Prevention Act is practically a dead letter. So far as the metropolis is concerned, the Metropolitan Board is, in the name of the ratepayers, a licensed polluter. Far be it from us to lend the least sanction to some of the wild schemes that have been held out by various companies and individuals to cure these evils. But here we have some undeniable facts. We have a river running through London for a distance of, say, twenty miles, which nominally carries away, but really retains, the sewage of 4,000,000 persons. From its surface there exhale noxious gases, and on its banks equally noxious manufactures are carried on. The Statute Book shows laws against all these evils, but the most interested parties to retain the evils are those who have to put such laws into force. If this is not putting into defiance all common sense and sanitary improvement, we should be at a loss to find another instance. Meanwhile the kings play while the common people perish. The Board of Trade falls out with the Metropolitan Board, the Thames Conservancy with the latter, the Courts of Chancery are afraid to stir, and "grant time," and thus, year after year, matters progress nominally, while if we take the veil off the sight, we find ourselves gradually walking backwards, or, to use more modern and political phraseology, in a state of retrocession to conditions that were abominated twenty years ago.

THE CONSERVANCY OF RIVERS AND STREAMS.

By EDWARD EASTON, Esq., President of the Section of Mechanical Science.

Paper read before Section G of the British Association—Dublin Meeting.

By the conservancy of rivers and streams I mean the treatment and regulation of all the water that falls on these islands from its first arrival in the shape of rain and dew to its final disappearance in the ocean.

I had at first, in my ignorance, contemplated treating the subject in a still wider manner by referring to the rivers and streams of other countries; but I soon found that, without going beyond our own, the vast extent of the field to be traversed would make it extremely unlikely that I could, with any satisfactory result, attempt even the more restricted task which I have now before me.

The question of conservancy of rivers and streams involves the consideration of their regulation for the following principal purposes:

1. For the supply of pure and wholesome water for the domestic and sanitary wants of the population.

2. For the supply of water of proper quality and sufficient quantity for industrial purposes.

3. For the proper development of water power.

4. For the drainage and irrigation of land.

5. For navigation and commerce.

6. For the preservation of fish.

In the early days of the world's history there were attempts made to regulate and control the waters of rivers—some of them devoted to military and dynastic objects, but the majority to generally useful ends. Herodotus, speaking of Semiramis, who lived some 2000 years B. C., tells us that she raised certain embankments, well worthy of inspection, in the plain near Babylon, to control the River Euphrates, which till then used to overflow and flood the whole country round about. He also mentions a lady, who lived at a still earlier period, who altered the course of the same river, as a defence against the Medes, to such an extent that, "whereas the River Euphrates ran formerly with a straight course to Babylon, Nitocris, by certain excavations which she made at some distance up the stream, rendered it so winding that it comes three several times within sight of the same village" (Ardericca, in Assyria). "She also made an embankment along each side of the Euphrates, wonderful both for breadth and height, and dug a basin for a lake a great way above Babylon, close alongside of the stream, which basin was sunk everywhere to the point at which they came to water, and was of such breadth that its whole circuit measured 420 stadii (more than 50 miles). The soil dug out of this basin was used in the embankments along the water side. When the excavation was finished she had stones brought, and bordered with them the entire margin of the reservoir. These two things were done—the river made to wind, and the lake excavated—that the stream might be slacker by reason of the number of curves and the voyage rendered circuitous, and that at the end of the journey it might be necessary to skirt the lake, and so make a long round. All these works were on the side of Babylon where the passes lay, and the roads into Media were the straightest; and the aim of Nitocris in making them was to prevent the Medes from holding intercourse with the Babylonians, and so to keep them in ignorance of her affairs." The same energetic princess made brick embankments and quays, and a bridge over the Euphrates, and to do this she turned the entire stream of the river into an artificial cutting, the natural channel being left temporarily dry until the bridge was finished, when the Euphrates was allowed to flow into its ancient bed. It was into this very cutting that Cyrus directed the course of the Euphrates when he took Babylon, 538 B. C. In the time of Herodotus himself, about B. C., 450, there were embankments to the river at Babylon; for he says, "the city wall is brought down on both sides to the edge of the stream; thence from the corners of the wall there is carried along each bank of the river a fence of burnt bricks, with low brazen gates opening on the water."

The same historian, in his second book, describes the hydraulic works of the first king of Egypt, Men or Menes, which were not only gigantic in themselves, but productive of the most important results to the inhabitants of his kingdom. "Before his time," Herodotus says, "the river flowed entirely along the sandy range of hills which skirt Egypt on the west side. He, however, by banking up the river at the bend which forms about 100 furlongs south of Memphis, laid the ancient channel dry, and dug a new course for the stream half way between the two lines of hills.

Passing to Greece, perhaps the most wonderful instance of the successful regulation of water is to be found in the subterranean channels (the modern Greek Katabothra) by which the waters of the River Cephius are carried through Lake Topolias (the ancient Copias) into the sea. These tunnels, which are partly natural and partly artificial, have always served to prevent the lake overflowing the adjoining country.

The well-known tunnel, or emissarium, from the Alban Lake is an example of Roman work. This tunnel, of a man's height, and cut through 6000 feet of lava, is said to have been begun in obedience to the Delphic oracle in the sixth year of the siege of Veii, B. C. 398. By it, the over-flow of the lake which used periodically to flood the Campagna was

prevented, and the waters were conducted through it in an even flow for the irrigation of the fields which it had formerly laid waste. Three vertical shafts and one made in an oblique direction still remain; the marks on the hard rock show that the chisels employed in the cutting were an inch in width. Another Roman work of still greater importance was the emissarium at Lake Fucino, planned by Julius Cæsar and carried into execution by Claudius. This was a tunnel three miles in length, extending from the lake to the River Liris (the modern Garigliano), one mile of it being driven through a mountain of cornelian rising 3000 feet above the lake. It employed 30,000 men for eleven years. There are many perpendicular shafts for raising the rock to the surface and lateral galleries for disposing of the spoil, so as to enable this large number of men to work without interfering with each other.

The supply of water to different cities of the ancients has been the motive for the execution of the most stupendous works, which are almost numberless. It will be sufficient for me to allude to the works constructed for the supply of the city of Samos, about the time of Polycrates, B. C. 530, in which case a tunnel was driven through a hill 150 fathoms high for a length of 7 furlongs. Its height and width were each 8 feet, and it conveyed the water from the River Ampelus into the city. Herodotus tells us that the architect was Eupalinus, the son of Naustrophus, a Megarian. Sir George Wilkinson, in a note on the text, mentions the fact that a French traveler, M. Guérin, discovered one mouth of this tunnel to the north-west of the harbor of Samos, and cleared it from sand and stones to a distance of 540 paces.

It is sometimes asserted that the ancients were ignorant of the hydrostatic law that water finds its own level. This is not the case. Frontinus, who preceded Agricola, the father-in-law of Tacitus, as Governor of Britain, and who was Curator Aquarum in Rome under Nerva and Trajan, mentions in his book, "De Aquæductibus Urbis Romae," that in case of the fracture of an aqueduct, the water could be dammed up at each side of the point of fracture, and carried over the intervening space in leaden pipes. A great deal of the internal distribution of the water in Rome was managed by leaden pipes under pressure.

The aqueduct which Herod is said to have constructed for the supply of Jerusalem crossed a deep valley—near Rachel's Tomb—by means of a stone pipe working under pressure. This work has been fully described by Mr. Telford Macneill in the report made by Sir John Macneill to the committee for supplying Jerusalem with water. The construction of the pipe is so remarkable that I shall give Mr. Macneill's description in detail. It consists of great blocks of stone through which holes 15 inches in diameter have been cut. One end of each block has been hollowed out to a depth of 4½ inches, with a diameter of 24 inches, thus leaving a recess 4½ inches wide to form the socket of the pipe. The other end has a projection of a size to fit a similar socket in the pipe which lies next to it. This answers to the spigot a modern cast-iron water-pipe. Both socket and spigot are ground, so as to fit with great accuracy, and the joint is made with cement, which has set as hard as the stone itself. The whole line of these stone pipes is surrounded with rubble masonry. The pressure on the center of this very remarkable inverted siphon is not less than 70 lbs. per square inch.

The Arabs at a later period not only knew of this law, but also understood the operation of what we engineers call the "hydraulic mean gradient." The aqueducts constructed by them for supplying Constantinople with water have been very fully described in the most interesting "Letters from Turkey," written by Field-Marshal von Moltke in the years 1835 to 1839. He says that the Arabs knew that water under pressure reaches its own level (*seich gleich stellt*), for they conveyed the water across the valleys in leaden pipes. They had found by experience that the friction through the aqueduct was lessened if openings were made in the course of the line of pipes; and along hill-sides and in places where the pipes are not in deep cuttings, funnel-shaped shafts or wells are made, which acted as air-holes. But in crossing deep valleys, where, of course, no such holes could be made, they built stone pyramids, called "Suterasi," or

water-balances, on the top of which they placed small basins, into and out of which the water was conducted by a leaden pipe laid up on one side of the pyramid and down the other. The level of these basins was so arranged that they were at an inclination rather greater than the average fall of the aqueduct; and thus they allowed the water to take the hydraulic mean gradient due to the head necessary for the delivery of the water. It is probable that these "suterasi" were made about 1000 A. D.

In Britain the Romans without doubt constructed embankments for the control of rivers, but for at least 1000 years after their time very little was done in the way of great public works of this description; and it was not until the beginning of the sixteenth century that the state of the rivers in Italy commanded the attention of the great land-owners and scientific men of that country. At that time, chiefly in consequence of the appointment of a Commission in 1516 by Francis I, works for remedying existing evils were seriously thought of: and for a long series of years the most eminent mathematicians and engineers were engaged in investigating the subject and in designing and carrying out works of greater or less magnitude. A very full collection, both of the writings of these Italian engineers and of the descriptions of their works, is contained in a book of thirteen volumes, published at Bologna, in 1821-24, entitled "Raccolta d'Autori Italiani che trattano del Moto dell'Acque." It would seem that about the same time the question began to excite interest in England, for it was in the reign of Henry VIII, that a public statute first dealt with river conservancy. But it is to be remarked that neither in Italy nor in England was the question treated in anything like an exhaustive manner. The great hydraulic works of Italy relate almost exclusively to irrigation and navigation, whilst the drainage of lands and the prevention of floods were the objects of legislation in England. During the same period the Dutch were of course constructing many important hydraulic works; but these, from the special circumstances of the country, were not such as to have much bearing on the general question of the conservancy of rivers.

After the drainage of the Fens, the next great works in England were the canals, which, in a very few years, extended over the whole of England, and formed a complete system for the conveyance of traffic. It is superfluous to say that their construction and maintenance had a strong bearing upon the regulation of rivers. The well-known saying of Brindley that rivers were "principally valuable for feeding canals" sufficiently indicates the subserviency of the other interests involved. Next the introduction of railways and steamboats, and the increase in the size of ships, turned the attention of those interested in rivers to the improvement of the tidal harbors and channels; and from that time to the present the greatest hydraulic works of our time have been connected with navigation. The concurrent increase in manufactures necessitated the employment of water in ways apparently antagonistic to other interests, and introduced the new element of pollution of our rivers and streams, whilst the demands of sanitary legislation, consequent on the great increase of population, made it imperatively necessary that their purity should be maintained. Indeed, we may say that the present high state of civilization in which we live has involved greater complications in this as in other departments of life, and requires special arrangements to meet them.

Legal enactments for the regulation of rivers, and for defining the rights of property in water, have existed from very early times. Solon laid down that to intercept the supply or to corrupt the quality of water is a crime. He also enacted that if any one dug a well to a depth of ten fathoms (ὀργυῖαι) without finding water, he should be permitted to take from his neighbor's well a pitcher of six χόες (about 18 quarts) twice a day. Plato, in his Laws, mentions an analogous provision, but confines it to drinking water only. Another law quoted by him is more to the point; it runs as follows: "If after heavy rains any of the lower riparian proprietors should injure a neighbor who lives above them, by stopping the downward flow of the water, or in case, on the other hand, the proprietor living higher up shall injure his neighbor below, by negligently allowing the water to run down upon him, either of them may call in the magis-

trates and obtain a decision for the guidance of both parties. If either party fail to abide by such decision, he shall be punished for the enviousness and peevishness of his spirit, and shall pay double damages to the injured person."

The Pandects of Justinian, which are a collection of all the old legal authorities of Roman law, analogous to our own reported cases, contain a variety of leading principles which govern the administration of the law of running water: principles identical mainly with that of our own common law. Some of these related to fishing, watering cattle, to the interruption of navigation of lakes, canals, and ponds, to the preservation of the water supply, to the repairs of river banks, and to the regulation of the summer and winter flow of what are termed public rivers. It was enacted among other things, that nothing should be done to the stream or banks of a public river, whereby the flow should be altered from its state in the preceding summer.

The earliest record in our own statute law of any enactment relating to rivers is that contained in 25 Edward III, c. 4, which legalized all "gorces, mills, wears, stanks, stakes and kiddles," of a date previous to "the reign of his grandfather Edward I, by which the common passage de neefs et batelx en les grantz rivers d'Engleterre be oftentimes annoyed," and ordered the immediate pulling down of all such erections which were of a later date.

From that time, until the enactment of Henry VIII, there were various laws passed, chiefly relating to the navigations and rights of mills, and occasionally to the preservation of fish. After Henry VIII, very many private acts and charters granting powers for the drainage and reclamation of lands, for improvement of navigation, and matters of a similar kind, were passed from time to time. A great number also of royal commissions and select committees have conducted inquiries, and made reports upon most of the various branches of the subject, *e. g.* the pollution of rivers, the water supply, arterial drainage, navigation, fisheries, &c., but until the appointment last year of the Select Committee presided over by the Duke of Richmond, no attempt, as far as I am aware, has been made to grapple with the question as a whole, and the report made by them to the House of Lords omitted to deal with, at least, two of the objects I have indicated as being necessary to the proper consideration of the subject.

The recommendations made in the report of that Committee were most important, and they will, if carried out, remove many of the difficulties which stand in the way of a complete system of conservancy of our rivers.

So much has been written on the engineering details of this subject, by men far better qualified than I am to deal with them, that I shall confine myself to the simple statement of the principles which have been recognized by the chief authorities as essential, and to a few suggestions, which my own experience leads me to think may be of some value. Almost all the great engineers of former generations, who have paid attention to this question, Smeaton, Telford, Rennie, Golborne, Mylne, Walker, Rendel, Stephenson, Jessop, Chapman, Beardmore, and without mentioning names, many of the most eminent now living, have agreed to the following general propositions:

That the freer the admission of the tidal water, the better adapted is the river for all purposes, whether of navigation, drainage, or fisheries.

That its sectional area and inclination should be made to suit the required carrying power of the river throughout its entire length, both for the ordinary flow of the water, and for floods.

That the downward flow of the upland water should be equalized as much as possible throughout the entire year; and

That all abnormal contaminations should be removed from the streams.

In carrying out these principles, it is perhaps superfluous to say, that modifications must be introduced to suit the particular phenomena of each river. In some watershed areas, it would be easy to construct reservoirs, which would to a great extent equalize the flow and reduce floods. In others it might be better to control the floods by means of embankments. In others, to have weirs, and sluices, delivering into side channels, parallel to the main stream, with the same object. Sometimes reservoirs or receptacles, must be made for catching the débris brought down by the streams. In fact, every river must be treated as a

separate entity. It is therefore necessary that a systematic collection of data, relating to rainfall, the geological character of the gathering ground, and the volume of each separate stream, should be made for each watershed area; and this should be carried on for a sufficient length of time to enable a fairly correct estimate to be formed of the behavior of the river both in time of flood and in time of drought. The establishment of self-acting tide-registering gauges at several points of every outfall should be insisted on. By these means the whole of the phenomena of a watershed area could be ascertained and recorded, and safe and trustworthy knowledge could be obtained, which would contribute towards the determination, not only of the works which ought to be executed, but of the incidence of the taxation by which the necessary funds should be raised. For instance, it is obvious that where the geological character of a watershed is variable, one portion of it consisting of a permeable stratum, such as chalk or red sandstone, and another portion of an impervious stratum, such as the tertiary clays or the shales of the millstone grit, the same works would not be adapted to each section of the river, nor would it be fair to charge all the expense according to the same scale of contribution. The former, that is the permeable stratum, is not only, from its absorbent nature, not the cause of floods, but is, by reason of that characteristic, absolutely constituted by nature one of the very works which must be devised by art to mitigate the effects of rainfall on the latter, or impervious stratum.

Bearing this in mind, I have often thought that nature might be usefully imitated in this operation, by passing the surplus rainfall into the permeable strata of the earth by means of wells, or shafts, sunk through the impermeable strata overlying them. This has been done in isolated cases for the drainage of lands, but not for the deliberate purpose of preventing floods and equalizing the flow of rivers.

I also wish to remark that artificial compensating reservoirs may be much more frequently made use of than is generally supposed to be possible, when it is considered that, so long as the dams are constructed in situations where there is no danger of their giving away, it is by no means necessary that they should be water-tight, and that, therefore, they can be constructed at a very much smaller outlay. In fact, the purpose would be answered by a series of open weirs, which would collect the water in times of flood and discharge it gradually down the stream.

The example of our French neighbors in the more general use they make of movable weirs—*barrages*—of various constructions could, I am satisfied, be followed by us with very great advantage in many cases.

The question of water power is one which, I think, deserves more consideration than it has lately received. It has been the fashion to consider that small water mills are of little or no value, and, in the present state of most rivers and streams, this is to a very great extent true, but only because the supply of water to work them is so variable and uncertain. Sufficient attention has never yet been given to the subject of the amount of compensation water which should be given for the use of riparian proprietors, when the watershed areas are dealt with for purposes of water supply. There is a kind of empirical rule acknowledged by most of the eminent water engineers, that one-third of the average flow of three consecutive dry years is a fair equivalent for the abstraction of the water falling on a gathering ground. I am strongly of the opinion that, looking to imperial interests, advantage should be taken of every opportunity of dealing with a gathering ground to provide for a much larger proportion of its available water being sent down the streams, so that the natural water power of the country may be properly developed. The extra cost of the necessary works must, as a matter of course, be borne rateably by the interests benefited. It is certain that with the progress of invention many more ways of utilizing this power will be discovered. At present, through the medium of compressed air, of hydraulic pressure, and of electro-motors, the great disadvantage of its being only available at the spot where the water runs is overcome, and the power can be transmitted to any distance, and used wherever it may be most conveniently applied.

Sir Robert Kane, in his most valuable and exhaustive work on the "Industrial Resources of Ireland," has given an estimate of the value of the power allowed to escape every year in the shape of floods, and the same calculation might be applied to the sister kingdom. It is probably no exaggeration to say that where running streams exist the power required for estate purposes, on the majority of properties in the United Kingdom, might be obtained by a proper conservation of the natural water resources of those streams.

The consideration I have been able to give this subject, has helped to convince me that, although a vast amount of labor and research has been devoted to it, it is nevertheless one in which "a more systematic direction to scientific inquiry" is urgently needed.

A vast collection of scientific facts exists, but they require arrangement and collation, and future observations should be more strictly classified, so that the bearing of each one, both on the others and on the subject at large, may be properly appreciated with a view to a practical result.

In France this is being done to a very large extent, and an excellent map showing the phenomena of the rivers and streams of that country is now in course of preparation. For many years also very accurate observations of the phenomena of the whole of the basin of the Seine have been taken, and have been centralised (*centralisées*) by that eminent engineer, whose loss, all who had the privilege of knowing him, either in his work or in private intercourse, are deploring, M. Belgrand, late Inspector-General of the Ponts et Chaussées, and by his able coadjutor, M. M. G. Lemoine. These observations have been published in the form of diagrams, admirable in their simplicity of design, which show at a glance the bearing of every one of those phenomena on the general character of that river.

In Italy also, where there exists a distinct department having control of the hydraulic works of that country, the same exhaustive system of collation and record has been followed, and the results have been published in a series of Tables. In Germany, although the same complete system is not in vogue, its chief river has been the subject of most thorough investigation, the results of which have been published in a beautiful map of the Rhine and its regulating works.

In our own country, as might be expected from the number of engineering works which have been executed, there probably exists an amount of detailed information on special and often minute points which is unsurpassed and, probably, unequalled in the world.

But, although as I have said before, a great number of eminent men have treated in an exhaustive manner the phenomena relating to many of the principal rivers of Great Britain and Ireland; yet, as far as I am aware, there has been no attempt to collect and combine these most valuable, though detached fragments of knowledge, so that their relation to one another might be seen, and a general conclusion arrived at. This can only be done by the establishment of a public department analogous to those described as already existing in France and Italy.

I do not wish to be understood that, in suggesting the collection of additional data relating to the phenomena of rivers, I am advocating delay in dealing with the existing state of things until the facts have all been ascertained. On the contrary, I believe that the first step ought to be the establishment of a distinct water department, which should at once address itself to the remedying of the evils which are found to be most pressing. The time has long since arrived when the present neglected state of many of our most important streams should be dealt with, and that this was also the conviction of Parliament and of the Government is evident, from the appointment of so influential a committee as that presided over by the Duke of Richmond last session.

Even the imperfect sketch which I have been able to place before you will have made manifest, I think, the enormous importance of the subject and of the interests involved—interests subject to periodical losses arising from the present imperfect organization, or I may say, the present entire want of organization—losses which are not only monetary, and therefore to a certain extent capable of being estimated, but which affect health and imperil life, and on that

account, as is the unhappy experience of the highest as well as the lowest of the community, utterly incapable of appreciation. How, for instance, can we estimate the loss sustained by the country at large by the premature death of that noble-minded and accomplished gentleman, the Prince Consort, whose life and energies were devoted to the encouragement of all the objects which this Association is established to foster and promote, and who showed his strong sense of its usefulness by presiding at one of its most brilliant meetings.

When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entailed a monetary loss of several millions sterling in the three kingdoms—that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds—that there is a constant annual expenditure of enormous amount for removing débris from navigable channels, the accumulation of which could be mainly, if not entirely prevented, that the supply of food to our rapidly growing population, dependent, as it is at present, upon sources outside the country, would be enormously increased by an adequate protection of the fisheries—that the same supply would be further greatly increased by the extra production of the land when increased facilities for drainage are afforded—that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed, that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

A new department should be created —one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river basin, or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament.

The department should have entire charge of, and control over, all estuaries and navigable channels, both because these are used by foreign vessels, and therefore the responsibilities attaching to their preservation are international, and because they must be protected from hostile attack, and on these accounts are essentially imperial property. For the same reason the cost of amending and maintaining them should be defrayed out of the Imperial exchequer.

As regards the regulation of the remainder of the water-shed area, the conclusions arrived at in the report of the Duke of Richmond's Select Committee seem to me entirely satisfactory. I cannot do better than give a few extracts from that report. The Committee say—"That in order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of conservators, who should be responsible for maintaining the river from its source to its outfall in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general direction of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body constituted of residents and owners of property within the whole area of the watershed." The committee go on to say that "means should be taken to insure the appointment of a Conservancy Board for each watershed area," but that application should first be made by persons interested in the district, and that then the departmental authorities should send inspectors to make local inquiries and to report upon the "necessities and capacities of the district, and suggest the area and proportions of taxation."

The scheme with such modifications as may be deemed necessary is then to be embodied in a provisional order to be submitted to Parliament for confirmation. It will be seen that this mode of

procedure is precisely analogous to that of the Local Government Board in relation to public health—a procedure which, as I am able to state from practical knowledge, works admirably in most cases. The committee further recommend that the provisions in any local or other acts which would interfere with the proposed scheme, should be repealed. They are also of opinion that "the Conservancy Boards should be enabled to execute the powers conferred on local authorities by the Rivers Pollution and Prevention Act." It will also be necessary that their powers should extend to the carrying out of any acts passed or to be passed for the protection of the fisheries.

With regard to what is probably the most important point of all, the finding of the money necessary to carry out these recommendations, the committee advocate the introduction of a new principle of taxation, the soundness of which cannot be questioned. Instead of the principle first introduced by the statute of Henry VIII, and observed ever since, of levying taxes in proportion to the direct benefit conferred, the committee propose that the rates should be distributed over the whole area of a watershed, including not only the lands, but the towns, and houses, and all other property situate within that area. This is in fact no more than a general application of the law of highways, which in the time of the Romans, according to Justinian, applied equally to waterways. It is perfectly just that every acre, the drainage of which contributes to the flow of the streams and rivers and of every watershed area, should in some proportion or other, contribute also to the cost of maintaining the channels of those streams and rivers in an efficient state. The incidence of the taxation must of course, as has been pointed out, be determined by the circumstances of each particular case, but there is no doubt that the conclusion of the Duke of Richmond's committee, that "the taxation should be levied on the basis of rateable value," is the only sound, and at the same time practical way of dealing with this difficulty.

The word "taxation" is not, I fear, generally connected with any idea of profit to the individual taxpayer. But in this case, as I hope in the course of this address I have made clear, it is probable that the prevention of large present losses, and the advantages gained by an improved system, will give not only a fair but an ample return on the capital expended.

It is my firm belief that an intelligent management of watershed areas would be compatible with an absolute profit to every interest affected; that we have here no question of give and take, but that in this, as in every other case, the laws of nature, under proper and scientific regulation, can be made subservient to the needs of the highest civilization.

BRICKS AND BRICKMAKING.

From "The Builder."

THE science of agriculture no doubt afforded the earliest scope for the exercise of human skill and industry. The Biblical narrative speaks of Abel as a "keeper of sheep," and of Cain as a "tiller of the ground." An application to the mechanical industries allied with arts of construction must, however, have been very early forced upon man, in order to supply implements of husbandry and to provide places of habitation. We read in the fourth chapter of Genesis that Tubal-cain was "an instructor of every artificer in brass and iron," or, according to Gesenius, "a sharpener of every kind of brazen and iron instrument"; a reference clearly pointing to the manufacture of tools required for the purposes of the husbandman and probably of others used in connection with constructive art, then in its rudest infancy.

There is little doubt that clay, in combination with such materials as would bind it together in a compact mass, was employed in the structure of the primi-

tive human dwelling. In course of time this method of construction was superseded by the use of the same plastic substance, moulded, either with or without other ingredients, into suitable forms, which were afterwards dried or burned, the result being the production of the article now known as "brick." The descendants of Noah are described in Genesis xi. 3 (2247 B.C.) as making bricks and burning them thoroughly, afterwards laying them with "slime,"—or, as some translators read, "bitumen,"—in the place of the mortar now employed for the same purpose. With the bricks thus made they built the tower of Babel "on a plain in the land of Shinar." Some of the best authorities agree in regarding the ruins still standing at Birs-Nimrud, to the south-west of Hillah, near the Euphrates, as being the remains of this tower; and it is a remarkable fact that, after the lapse of ages, the bricks of which it is constructed are so firmly embedded in the bitumen used as mortar that it is no easy task to detach or extract one. The circumference of the tower measures 762 yards, and a conical elevation on the western side rises to the height of 198 feet. The various stages of brickwork are of different colors,—a result which must have been attained by some special process, the ordinary Mesopotamian brick being of a pale yellow or whitish colour. The late Mr. George Smith, the indefatigable Assyrian explorer, deciphered among the tablets in the British Museum a history of the building of this tower, which will be found in his "Chaldean Account of Genesis."

The mounds of Assyria and Babylonia abound with bricks, sun-dried and burnt, Rawlinson, Layard, Mignan, Rennel, and other travelers having found them in incalculable quantity. Modern research has also confirmed the statement of Herodotus, that from the clay thrown out of the trench surrounding the ancient Babylon, bricks were made and burnt, which were used in building the massive walls of the city. The buried palace of Nebuchadnezzar on the Euphrates is said to have furnished bricks for the erection of all the buildings in its neighborhood for many years past; and we are told that "there is scarcely a house in Hillah which is not almost entirely built with them." Muller, in his "Science of Language," says that the ancient materials from the colossal palaces erected by the great ruler of Babylon were carried away for building new cities, and that Sir Henry Rawlinson discovered numbers of the bricks in the walls of the modern Bagdad on the borders of the Tigris. No doubt can exist as to their identity, owing to the custom which prevailed in Assyria and Babylonia of marking each brick with the name and title of the king in whose reign it was made, and also, in many instances, with the name of the place in the construction of which the brick was to be used. These inscriptions are in cuneiform characters, and were impressed upon the brick in a sunken rectangular panel, closely resembling that in which the name and trade-mark of modern manufacturers of moulded bricks now appears. From the presence of these inscriptions Sir Henry Rawlinson has been able to ascribe the manufacture of some of the bricks found by him to the period of the older kings of Babylon, who reigned about 2000 B.C. In form, the ancient Assyrian bricks closely resemble thick tiles, being generally from 12½ inches to 14½ inches square, and about 4 inches in thickness. They were almost universally shaped in a mould, some being rounded at the corners for quoins or special work. Generally speaking, they were of a pale yellow or red color. At Kouyunjik, Nimroud, and other places, however, bricks have been found glazed with a thick coating of different colors, some having subjects traced in outline upon them. The walls of the city of Nineveh are said to have been built with glazed bricks of this description, and those of the Median Ecbatana were constructed of colored bricks. Enameled bricks, brightly colored, have also been found in abundance in the mound of the Mujellibeh in Mesopotamia, the principal tints being a very brilliant blue, a deep yellow, red, white, and black.

In Egypt, bricks were used at a very early date, some of the most ancient Pyramids, built at least 2,000 B.C., being constructed of brickwork. The mud of the Nile has always been the sole material employed in the manufacture of Egyptian bricks, and the process at the present day is almost identical with that

adopted in the time of Thothmes III, the prince who is believed to have occupied the Egyptian throne at the period of the exodus of the Hebrews, about 1430 B.C. Brickmaking, there is reason to believe, was a royal monopoly in Egypt, and the bricks which have been found bearing the stamp of Thothmes III, are more numerous than those of any other monarch. Nearly all Egyptian bricks, both ancient and modern, are *adobe*, or sun-dried. A few burnt bricks have been found in river walls or hydraulic works, but their use was evidently very limited. Owing to the rich alluvial character of the mud of which the bricks are made, chopped straw or reeds, pieces of pottery, and other materials, are almost invariably used for the purpose of binding the clay together. The modern process is to form a trough or bed, into which mud and water are thrown, together with large quantities of cut straw. The mixture is tramped into a mortar, taken out in lumps, and then shaped, either by hand or in moulds, into the required forms. A painting discovered upon the walls of one of the tombs at Thebes, in which the processes employed in manufacturing bricks are represented with striking minuteness of detail, shows how closely these resemble the method still adopted in Egypt. Some of the workers are depicted as engaged in digging the mud, and mixing it in heaps with sand, while others carry the material thus prepared in baskets to the brickmaker, who is seen shaping it in the mould. Others, again, are employed either in laying out the bricks thus formed upon the ground to dry in the sun, or in bringing from the river, in jars upon their shoulders, the water required for tempering purposes. Laborers, too, are busily engaged in removing the dried bricks upon flat boards, two of these being slung by ropes attached to each end of a yoke placed across the shoulders. Taskmasters are also shown, watching over and directing the operations, stick in hand, ready to inflict summary punishment on the idle or the refractory. Brickmaking, it must be remembered, was regarded in Egypt as a degrading task, and was usually assigned to slaves. It formed the principal occupation of the Israelites during their bondage in Egypt, after the death of Joseph, and the grievous addition to their toil necessitated by the obligation to provide their own straw may be readily estimated from what has been already said as to the process of manufacture. The bricks made by them during their captivity were probably used in the erection of the great treasure-cities of Pithom and Rameses. At a later date, we read of the erection in Egypt of a brick pyramid by Asychis, the monarch whose reign immediately preceded that of Sethos, the contemporary of Sennacherib and Tirhakah, about 700 B.C. This would probably be one of the four brick pyramids still remaining in Lower Egypt in addition to those at Thebes. Two of these are close to the ancient Memphis and the modern Dashour, and the others are situated at the mouth of the Fyoom. They are built of sun-dried bricks, the chambers having arched ceilings. Brick arches are to be found, however, in buildings at Thebes of a much earlier date, the arch having been invented and used in Upper Egypt centuries before the reign of Asychis. The ordinary Egyptian brick approached somewhat to the modern type, being generally from 14½ inches to 16 inches wide, and of a thickness varying from 5 inches to 7 inches. In the older pyramids they were of an exceptional size, measuring in some cases 20 inches in length, and about 8 inches in width. The bricks of Egypt, like those of Assyria, bore the name of the kings in whose reign they were manufactured, but, in place of being inscribed, they were stamped, the hieroglyphs being in relief.

In Palestine, in the time of the prophet Isaiah, it is clear that bricks were used in the construction of private dwellings (Isaiah ix. 10), and one of the offenses laid to the charge of the people of Israel by the prophet was that of using brick in place of stone, for the construction of their altars (Isaiah lxv. 3).

Amongst the ancient Greeks, who devoted special attention to every branch of constructive art, the manufacture of bricks was placed under legal supervision and brought to a very high perfection. Pliny mentions three distinct varieties as being in general use, and alludes to the circumstance that the walls of the city of Athens, on the side towards Mount Hymettus, were built of brick. Many

of the principal public edifices in the leading cities of Greece were also of brickwork,—perpendicular walls of this construction being considered by the Greek architects more durable than those of stone.

Brickmaking was a flourishing industry in the Roman Empire, both sun-dried bricks (*lateræ crudi*) and kiln-burnt bricks (*lateræ cocti*) being extensively used in public buildings. All the great existing ruins of ancient Rome are of brick, and there is scarcely a province of the once mighty empire which does not still exhibit striking proofs of the durability of the bricks manufactured, and the skill of the artificers who laid them, in the days when Rome was mistress of the world. In the erection of the Coliseum, 80,000 captive Jews were employed, who probably helped to make the bricks of which the noble structure was built, as well as to lay them. The use of bricks in the construction of the public edifices of Rome was indeed so general as to afford occasion for the remark of the Emperor Augustus, with reference to the numerous and extensive architectural improvements he had carried out, that "having found the city brick, he had left it marble." To enumerate all the great public buildings which thus bear witness to the excellence attained by the Romans in the art of brickmaking would be tedious. Among the most notable, as illustrating the progress made at different stages of the history of the empire, are the Pillar of Trajan, the Bath of Titus (A.D. 70), and the Bath of Caracalla (A.D. 212). Notwithstanding this very general employment of bricks in the construction of public edifices, it may be inferred, from the observations of Pliny, that they were not commonly used in private houses, in the building of which wood was probably the chief material; a view which would seem to be, to some extent, confirmed by the extent and destructiveness of fires which occurred in ancient Rome. Pliny, after referring to the common use of bricks by the Greeks, condemns them as wholly unsuited for Roman dwellings, in which party walls were not allowed to exceed 18 inches in thickness, and that thickness he declares, "would not support more than a single story." At this period, the Roman bricks varied considerably in size, but were chiefly of three clases. The largest, known as the Lydian, were 1 foot 6 inches in length by 1 foot in breadth, and the others, which were respectively four and five palms in length, took their titles from their admeasurement. They were all very much thinner than the modern brick, more especially those employed as a bond in Roman rubble-constructions, which, in this respect, bore a close resemblance to the wall-tiles of the present day. The kiln-burnt bricks in the Greek building at Treves called the Palace of Constantine, are all "of a square form, 3 inches in diameter, and 1¼ inches thick." The custom of marking each brick, which has been alluded to as prevailing amongst the Assyrians and Egyptians, was maintained by the Romans, the various brickmakers having each their distinguishing mark. Every brick was stamped with the figure of some god, plant, or other symbol, encircled with the name of the maker, the consulate, and the legion by which it was used. The Twenty-second Legion has been traced through Germany by bricks which bear its name, and at Caerleon, in England, Roman bricks have been discovered with the inscription "Leg. II, Aug.," while others found at York attest the presence there of the Sixth and Ninth Legions. Some of these bricks were scratched on the surface, while others had lumps raised on them, or were deeply notched, with the view of making the mortar adhere more firmly. The Romans preferred, for brickmaking purposes, a clay which was either of a whitish hue or decidedly red. They considered Spring the best time for carrying on the process of manufacture, and it was the general custom to keep bricks two years in stock before laying them.

With the decadence of the Roman Empire, the art of brickmaking declined and fell into disuse, but, after a few centuries, experienced a complete revival, the Italian ecclesiastical and palatial architecture of the Middle Ages being distinguished by remarkably fine examples of brickwork and ornamental work in terra-cotta. Towards the close of the seventeenth century, an Italian, named M. Fabbroni, rediscovered an ancient invention, which had been completely

lost for many generations, namely, the manufacture of bricks sufficiently light to float in water. Strabo speaks of these bricks as having been made with an earth found at Pisane, in the Troad, and Poseidonius mentions others of a like character as having been made in Spain "of an argillaceous earth, wherewith vessels of silver are cleansed" (probably rottenstone). M. Fabbroni succeeded in producing these floating bricks from "fossil meal," an infusible earth found in abundance over a considerable area of certain districts in Italy. They were only one-sixth the weight of an ordinary clay brick, and on this account were highly esteemed for vaulting church roofs and similar architectural work. The earth of which they were composed consisted, according to Ehrenberg, the German microscopist, almost entirely of the siliceous skeletons of minute water-plants. The bricks with which the arching of the floor in the Berlin Museum is built were made from this material, in combination with a certain proportion of clay "slip."

Among many of the Asiatic nations, bricks of excellent quality have been made from a very remote period, and are to be found in buildings erected centuries ago. A very full account of the history of brick-making in India will be found in the "Professional Papers on Indian Engineering" of Major Falconnet, R. E., published in May, 1874.

In China, bricks are faced with porcelain, and in Nepaul they are richly ornamented by the encaustic process and in relief.

Brick-making was found by the conquerors of Peru to be a flourishing industry in the ancient empire of the Incas, and we have the testimony of Spanish historians, as well as that of Humboldt, Prescott, Stephens and Squier, that both in Peru and in the more northerly regions of Yucatan, and Mexico, there are still extant fine structures in brick, as well as in porphyry and granite, the work of races which have long since passed away.

The scarcity of stone in Holland and the Netherlands naturally led the inhabitants, at a very early period, to seek some other durable material for building purposes, and brick has been almost exclusively employed in the construction not only of private dwellings and commercial establishments, but of ecclesiastical structures and other public edifices. Very fine examples of brickwork in two colors abound, the most notable, perhaps, being at Leeuwardein, in Friesland. The material used in Dutch bricks is chiefly the slime deposited in the numerous rivers and arms of the sea. This is collected by men in boats, who use long poles, furnished at the end with a cutting circle of iron, and a bag-net with which the slime is brought to the surface. Bricks of exceptional hardness are made with a mixture of this slime and sand from the banks of the river Maas. Ordinary house bricks and tiles are chiefly made at Utrecht, from brick-earth found in the vicinity. For the production of the special make of bricks known as "Flemish bricks," which are manufactured in France, Flanders, and the corresponding Belgian frontier, sand from the Scheldt is principally used. At Ghent, as well as at other points lower down the river, the supply of this material constitutes an important branch of the trade of the district. In preparing brick-earth, the slime and sand are well mixed, and then kneaded together with the feet, special care being taken with this operation, so that a perfectly homogeneous mass may be the result. The mixture is then deposited in heaps, and is moulded and dried in the same way as in this country. The kilns used for burning vary in size, some being large enough to contain as many as 1,200,000 bricks. Peat is the fuel ordinarily used for firing.

England seems to owe the introduction of the art of brickmaking to the Romans. Some specimens of their work which have been discovered date back as far as A.D. 44. The bricks in these early examples are nearly all of the wall-tile form, the use of which, as a bond in rubble construction, has been already adverted to. These large thin bricks continued in use, under the same conditions, until about the time of the Norman Conquest, when regular masonry gradually superseded rubble-work. A casual reference in the Saxon chronicles shows that bricks were made under the direction of Alfred the Great, but these were probably the bonding bricks just mentioned. The earliest instance of the use of bricks

of the modern or Flemish type is said to be afforded in the work at Little Wenham Hall, Norfolk (A.D. 1260). These bricks are of a deeper red than those generally used in Suffolk and the adjacent counties, but paler in tint than the common red brick. The use of brick in England as an ordinary building material, even for important structures, does not seem to have become at all general until the reign of Henry VIII, although there are some few brick buildings of the two previous reigns. Herstmonceaux Castle, Sussex, and the Gate of the Rye House, in Hertfordshire, were built in the early part of the reign of Henry VI, and the following are among the best examples of erections in brick from this date to the close of the reign of Henry VIII :— Tattershall Castle, Lincolnshire, A. D. 1440; Lollards' Tower, Lambeth Palace, A.D. 1454; Oxborough Hall, Norfolk, A.D. 1482 (about); Gateway of Hadleigh Rectory, Suffolk, close of fifteenth century; the older portions of Hampton Court Palace, A.D. 1514; and Hengrave Hall, Suffolk, A.D. 1538 (completed). Thorpland Hall and the Manor House at East Barsham, both in Norfolk, were built during the reign of Henry VII, and the Parsonage at Great Snoring, in the same county, during that of his successor. The remains of these buildings exhibit some of the finest specimens of ornamental brickwork to be found in this country. Throughout the reign of Elizabeth, the employment of brick would seem to have been reserved for the construction of mansions and other extensive works. In common buildings, the method ordinarily adopted was that of filling in a framework of timber with lath and plaster; and, even when the use of bricks became general, they were only introduced in panels between a framework of timber. In the first year of the reign of Charles I (1625) the size of bricks was regulated by a special order, and from about this period their use seems gradually to have become more general in shops and private houses, for, on the rebuilding of that portion of London which was destroyed by the Great Fire in 1666, the new erections were all of brickwork. So rapidly did the use of the material spread that the 19th Car. II, cap. 11, fixes "the number of the bricks in the thickness of the walls" of the several rates of dwelling-houses of the period. The records of the Corporation of the City of London also furnish evidence of the favor with which brick had come to be regarded as a constructive material, for about this time a resolution was passed in the following terms : "That they (the City surveyors) do encourage and give directions to all builders, for ornament sake, that the ornaments and projections of the front buildings, be of rubbed bricks; and that all the naked parts of the walls may be done of rough bricks, neatly wrought, or all rubbed, at the discretion of the builder." A special feature of brickwork at the close of the seventeenth and commencement of the eighteenth century was the enrichment of house-fronts by the introduction of ornaments carved with a chisel. Mr. Dobson's treatise on "Brick and Tile Making," published in Weale's Rudimentary Series, contains a sketch of a house in St. Martin's Lane, built by a person named May, about 1739, which is a fine example of this species of work in red brick. Two fluted Doric pilasters support an entablature, the mouldings, flutings, and ornaments of the metopes, having been carved with a chisel after the erection of the walls.

In the year 1784 a duty of half-a-crown per thousand was imposed on bricks of all kinds (24 Geo. III, cap 24), the tax being raised ten years after to 4s. per thousand (34 Geo. III, cap. 15). In 1803 a classified schedule of duties on bricks and tiles of different qualities and sizes was substituted for the uniform duty hitherto imposed. Thirty years after (by the 3d Wm. IV, cap. 11), the duty on bricks was again raised, the common sorts being subjected to an impost of 5s. 10d. per thousand, while tiles were wholly relieved from taxation. These duties were the subject of a Commission of Inquiry in 1836, and in 1839 the 2d and 3d Vic, cap. 24, relieved the trade of the vexatious restrictions imposed by the schedule of duties hitherto in force, and re-established a uniform duty of 5s. 10d. per thousand on all bricks "of which the cubical contents do not exceed 150 cubic inches," without regard to their form or quality. In 1850, bricks ceased to be the subject of taxation, the duty being wholly repealed (13 Vic, cap. 9). The development of the

brickmaking industry during the first half of the nineteenth century may be estimated from the following statement, in round numbers, of the total make of bricks upon which duty was paid at the close of each decade from 1820 until the repeal of the tax :—1820, 914 millions; 1830, 1,100 millions; 1840, 1,400 millions; 1850, 1,700 millions. Four years later, it was estimated that the total number was considerably in excess of 2,000 millions, the capital employed in this branch of industrial enterprise at that period exceeding £2,000,000.

The employment of machinery in the manufacture of bricks appears to have had its origin either in this country or in the United States. Some of the earliest American patents were taken out in 1792, 1793, 1800, 1802, 1806, and 1807. The records containing the specifications of these inventions were unfortunately burnt in 1836. Prior to June of that year, 122 patents for brick and tile machines had been granted in the United States, and upwards of 500 have since been taken out. In England, as early as the year 1619, we find, among the Specifications of Letters Patent, that the eleventh granted was for the protection of the "Arte of making a certain engine to make and cast clay, &c." This first idea of a machine for making bricks consisted of a large pan or table, containing moulds, which were filled with brick earth and a heavy roller passed over them to force the earth into the moulds. The surplus clay was then scraped off the top, and the bricks were ready for ejection from the moulds. This was, no doubt, a somewhat crude arrangement, but it approaches closely, in principle, the most approved machines of the present day. We do not, however, meet with any record of the introduction of brick-making machines, the operations of which were regarded as a practical success prior to the year 1839, when Messrs. Cooke & Cuningham patented one, which was capable of turning out 18,000 bricks in ten hours. In November, 1859, Mr. J. E. Clift, of Birmingham, at a meeting of the Institution of Mechanical Engineers, read a paper describing Oates's brick-making machines, which were then in use at Oldbury. The crushing strength of the bricks made by these machines was said to be 8,024 lbs. per square inch as compared with 4,203 lbs. in bricks made by hand from the same material. The cost of Oates's machine was from £150 to £200, exclusive of the engine for driving it, and its turn-out averaged 12,000 bricks per day, or about twenty per minute. In 1861, Messrs. Dixon and Corbett had a machine in work in the neighborhood of Newcastle-on-Tyne which was driven by steam power, and turned out 1,500 bricks per hour. The years 1861 and 1862 were marked by special activity in the production of these machines, the patents granted during this period embracing the following :—Wimball's, Morrell & Charnley's, Green & Wright's, Basford's, Effertz's, Grimshaw's, Morris & Radford's, Poole's, Newton's, Sharp & Balmer's, Platt & Richardson's, Foster's, and Smith's. Up to the year 1868, forty-seven patents relating to bricks and their manufacture had been granted. During the last twenty years many new machines have been invented, and important improvements introduced, and probably over 200 patents for machines connected with the manufacture of bricks and tiles are at present on record.

Mosandria—Another New Metal. —According to the *Correspondance Scientifique* of July 30th, Dr. J. Lawrence Smith, Professor of Chemistry in the University of Louisville, Kentucky, has discovered a new metal belonging to the cerium group, and has named it mosandrium, after Mosander, whose researches on this class of metals are well known. The new earth, mosandria, from which the metal was obtained, differs from the rest of the group of which yttria is the head by its reaction with potassic sulphate, although what this reaction is we are not informed. From cerium oxide, mosandria differs by its solubility in very weak nitric acid and in alkaline solutions supersaturated with chlorine; from lanthanium by the color of its oxide and salts; and from didymium by certain dark rays in the bright part of the spectrum. We shall refer at greater length to this discovery in our next number, giving, if possible, the physical and chemical properties of the new element. —*Chemical News.*

A METHOD OF DEDUCING FORMULAE FROM EXPERIMENTS ON WROUGHT IRON PILLARS.

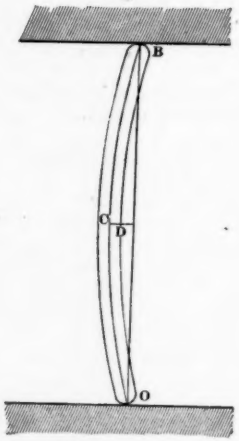
By JOHN D. CREHORE.

Contributed to Van Nostrand's Magazine.

Since the ordinary equation for the deflection of a beam is the equation of a parabola, with reference to the length l, and the deflection D, as the coordinates, let us assume that the equation to the curve of a given pillar sustaining a given load, is the equation of a parabola. Although this assumption may not entirely accord with fact, practically it cannot be very far from the truth, as will appear in the sequel.

Let Fig. 1 represent a pillar sustaining the weight or vertical pressure, P, with the deflection, D, length, l, and least diameter, h.

Fig. 1.



Then the equation to the curve of the neutral line BCO, is

$$y^2=2px.$$

if the origin is at C, and the axis of x horizontal, and that of y, vertical. But if O be taken as the origin and the axis of y horizontal, and that of x vertical, then the equation to the curve becomes, after eliminating p,

$$(x-\tfrac{1}{2}l)^2=\tfrac{1}{4}\frac{l^2}{D}(D-y).$$

$$\therefore\ x^2-lx=-\frac{l^2}{4D}\,y. \qquad (1)$$

Differentiating,

$$2xdx-ldx=-\frac{l^2}{4D}dy.$$

$$\therefore\ \frac{dy}{dx}=-\frac{4(2x-l)D}{l^2}$$

$$\frac{d^2y}{dx^2}=--\frac{8D}{l^2} \qquad (2)$$

But we have the radius of curvature

$$\rho=-\frac{\left(1+\frac{dy^2}{dx^2}\right)^{\frac{3}{2}}}{\frac{d^2y}{dx^2}} \qquad (3)$$

$$=\frac{[l^4+16D^2(2x-l^2)]^{\frac{3}{2}}}{8Dl^2}.$$

And, if $x=\frac{1}{2}l$,

$$\rho=\frac{l^2}{8D},$$

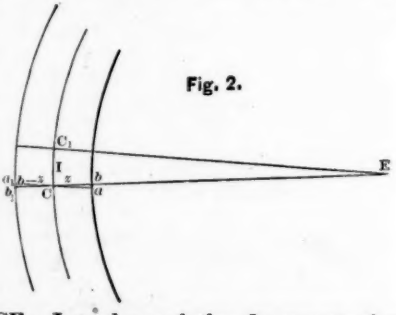
for the value of the radius of curvature at the center of the pillar.

This also follows from (2) and (3), since at the center,

$$\frac{dy}{dx}=o.$$

Suppose that C, Fig. 2, is the center of the neutral surface of the pillar, and that CC, is equal to a unit of the length of that surface, and that ρ, the radius of curvature at the center, is represented by

Fig. 2.



CE. Let ab equal the decrement of a unit of length on the compressed side of the pillar, and a_1b_1, the increment due to

the same unit on the extended side of the pillar. Take z equal to the distance of the neutral surface from the surface of the compressed side, and h equal to the least diameter of the pillar at the center. Then, according to the received theory, we have

$$\frac{1}{\rho}=\frac{ab}{z}=\frac{a_1b_1}{h-z}.$$

Whence

$$\frac{ab+a_1b_1}{ab}=\frac{h}{z}.$$

$$\frac{ab}{z}=\frac{ab+a_1b_1}{h}=\frac{1}{\rho}.$$

But $ab+a_1b_1$ is the total difference of length in the two sides of the pillar for a unit of its length. Therefore

$$\frac{ab+a_1b_1}{1}=\frac{h}{\rho}=\frac{2B_1}{E}=\frac{8Dh}{l^2}$$

and

$$D=\frac{B_1l^2}{4Eh} \qquad (4)$$

where B_1 is the unknown bending unit-strain on the fibres at the surfaces ab, a_1b_1 of the pillar, and E is the modulus of transverse elasticity.

Another expression for the central deflection may be derived from the equality between the total moments of the external and the internal forces in action.

The well known expression for the moment of the internal forces, is

$$M_x=-EI\frac{d^2y}{dx^2} \qquad (5)$$

where I denotes the moment of inertia (so-called) of the cross-section of the pillar, which is here supposed to be uniform throughout.

And the total moment due to the external force P acting vertically, and a force at each end producing a couple with the moment M_1, tending to diminish the deflection of the pillar, is

$$M_x=Py-M_1. \qquad (6)$$

$$\therefore\ -EI\frac{d^2y}{dx^2}=Py-M_1.$$

Hence from (1)

$$EI\frac{d^2y}{dx^2}=\frac{4PD}{l^2}(x^2-lx)+M_1. \qquad (7)$$

Integrating (7), first with the condition that $\frac{dy}{dx}=o$, when $x=\frac{1}{2}l$, and again with the condition that $y=o$ when $x=o$, we find after putting D for y and $\frac{1}{2}l$ for x,

$$EID=\tfrac{5}{48}PDl^2-\tfrac{1}{8}M_1l^2. \qquad (8)$$

If now we suppose the end moment M_1 to vanish, we have at once

$$P=9.6\frac{EI}{l^2},$$

and

$$\frac{P}{S}=Q=9.6\frac{Er^2}{l^2}; \qquad (A)$$

where S=the area, and r=the radius of gyration, of the cross-section of the pillar; and Q is the vertical pressure upon each unit of the cross-section of a pillar having rounded ends that can produce no end couples.

And here it may be noted that Weisbach, and Rankine, and Price, by a different method, find

$$P=\pi^2\frac{EI}{l^2}=9.8696044\frac{EI}{l^2},$$

the first remarking that the formula gives "generally a greater tenacity than the formula for the crushing strength"; the second, that this is the "smallest value of P which is compatible with any bending of the spring"; and the third, that "hereby also we are enabled to calculate the greatest weight that a vertical pillar of a given form and height can bear without being bent by the weight."

Examples of the application of formula (A), are given below.

Resuming equation (8), we have, if the equal end-moments do not vanish,

$$M_1=\tfrac{5}{6}PD-\frac{8EID}{l^2} \qquad (9)$$

Also from (6), the moment at the center is

$$M_c=PD-M_1 \quad \text{for external forces.}$$

$$=\frac{2B_1I}{h}, \quad \text{for internal forces.}$$

$$\therefore\ \tfrac{1}{6}PD+\frac{8EID}{l^2}=\frac{2B_1I}{h}$$

and, after dividing by S,

$$D=\frac{12B_1r^2l^2}{(Ql^2+48Er^2)h} \qquad (10)$$

which is the second expression sought for the deflection.

Equating (4) and (10) there results, $Ql^2=o$, which is absurd.

The source of this absurdity may be found in equation (4); for since that value of D was derived from curvature alone, it is the value which D would have from the unit-strain B_1, if B_1 were produced only by couples applied at the ends of the pillar, without direct longitudinal pressure. It is plain, therefore, that the unit-strain B_1 corresponds to a smaller deflection when it is produced by direct end-pressure, than when it is produced by end-couples. The value, $\frac{B_1 l^2}{4Eh}$, given by (4), is, therefore, too great, since we assume the unknown value of B_1 to be the same as the value of B_1 in (10).

Let us, therefore, correct equation (4) and write

$$D=\frac{B_1 l^2}{(4+\varepsilon)Eh} \qquad (11)$$

so that from (10) and (11) we find

$$\varepsilon=\frac{Ql^2}{12Er^2} \qquad (12)$$

Now if, by resorting to experiments, we can find some function of ε which shall be constant within given limits of $(l\div r)$ or $(l\div h)$, we shall have within those limits, a formula for the value of Q in terms of l, r, E, and ε.

The values of ε in the following tables have been computed from the experiments upon wrought iron pillars, given in Stoney's "Theory of Strains," and in Lovett's "Report on the Progress of Work, etc., of the Cincinnati Southern Railway."

The tests, tabulated in Mr. Stoney's Work, were made under the supervision of Mr. Hodgkinson, and those recorded by Mr. Lovett were made at Pittsburgh and Chicago under competent engineers.

Neither of these sets of experiments is so nearly complete as would be desira-

I.—Solid Rectangular Pillars—Flat Ends.

See Stoney's Theory of Strains, page 263. Modulus of Elasticity, E=24,000,000 . $r^2=\frac{1}{12}h^2$.
r=radius of gyration, h=least diameter, l=length of pillar, b=breadth.

$Q=\frac{P}{S}$=resistance, in lbs. per square inch.

Gordon's Formula, as applied by Stoney to this case, is,

$$Q=\frac{35840}{1+\frac{l^2}{3000\,h^2}}.$$

No.	b ins.	l ins.	$\frac{l}{h}$	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by		
						Formulae B, C, D, E.	Formulae B, C, F.	Gordon Formula.
1	2.980	120	238.569	1.9351	816	0	0	+ 978
2	2.983	90	179.176	3.2238	2,410	0	0	+ 653
3	3.010	120	156.658	3.4553	3,379	− 172	− 190	+ 525
4	2.995	120	120.603	2.5939	4,280	+1131	+1151	+1848
5	2.980	60	118.343	3.2702	5,604	+ 15	+ 13	+ 719
6	2.980	60	118.343	3.2988	5,653	− 34	− 157	+ 670
7	3.005	90	90.452	3.1636	9,280	+ 339	+ 375	+ 336
8	5.860	90	90.407	3.3756	9,912	− 283	− 257	− 289
9	1.024	90	87.891	3.1392	9,753	+ 435	+ 346	+ 273
10	3.000	120	79.470	2.6743	10,165	+2296	+2054	+1377
11	3.010	60	78.227	3.3068	12,969	− 108	− 115	−1179
12	3.010	60	60.301	2.7374	18,067	− 701	− 648	−1865
13	5.480	60	60.241	2.6760	17,698	− 319	− 279	−1479
14	2.986	30	59.689	2.5019	16,853	+ 651	+ 566	− 470
15	3.000	90	58.824	2.8816	19,987	−2285	−2421	−3343
16	1.024	60	58.594	2.4702	17,268	+ 491	+ 358	− 555
17	3.010	30	39.319	1.6793	27,767	−3545	−6161	−4115
18	3.000	30	30.121	1.1210	29,655	+ 145	−5021	−2137
19	1.023	30	29.326	.9075	25,327	0	− 400	+2527
20	1.023	15	14.663	.3095	34,554	+ 559	− 758	−1105
21	1.023	7.5	7.331	.1090	48,682	0	+1257	−13473

ble, but they are offered as the best at hand. Mr. Lovett says, "In order to test thoroughly the mathematical correctness of the formula [Gordon's] experiments should have been made with the same pressure on columns of different lengths and shapes of cross-section, made of the same iron, of uniform quality, and all fittings made, and measurements taken with great precision. All these conditions could not be realized."

In all the Hodgkinson tests here considered, E, the modulus of transverse elasticity is taken at 24,000,000; which is about the mean value of E found for such iron by that experimenter. For the Chicago and Pittsburgh tests, the values of E are given, and the mean value 27,311,111 has been used except in the case of "rounded or hinged ends."

From the tabulated values of ε we may derive formulae as follows:

1. Take the arithmetical mean of all the values of ε corresponding to $(l \div h) > 60$ and $(l \div h) < 180$, except the anomalous values in Nos. 4 and 10. This mean is $3.27916 = \varepsilon$.

We have, therefore, ε itself approximately constant between these limits of $(l \div h)$.

$$\therefore \varepsilon = \frac{Ql^2}{12Er^2} = \frac{Ql^2}{Eh^2} = 3.27916,$$

$$Q = 3.27916E\left(\frac{h}{l}\right)^2 = 78699836\left(\frac{h}{l}\right)^2 \quad (B)$$

when $(l \div h) \begin{cases} > 60 \\ < 180. \end{cases}$

2. For values of $(l \div h)$ not greater than 60, we observe that the product

$$\frac{h}{l} \times \varepsilon \times Q,$$

is a function of ε approximately constant.

Using Nos. 12, 13, 14, and 16, and taking means, we have

$$l \div h = 59.65,$$
$$\varepsilon = 2.5964,$$
$$Q = 17{,}427.$$

$$\therefore \frac{Q}{17427} \times \frac{h}{l} \times 59.65 \times \frac{Ql^2}{Eh^2} = 2.5964,$$

$$Q = 134927\sqrt{\frac{h}{l}} \quad (F)$$

when $(l \div h)$ is not greater than 60.

3. For the extreme value of $(l \div h) = 238.569$, we may proceed as follows; but the formula may not be reliable for other cases, there being no intervening series to give a law.

	No. 1.	No. 2.	Dif. of logs.
log. $(l \div h)$,	2.3776132	2.2532793	0.1243339
" ε	0.2867054	0.5083644	0.2216590

$$\text{Ratio of dif. of logs.} = \frac{.2216590}{.1243339} = 1.78277.$$

$$\therefore \varepsilon\left(\frac{l}{h}\right)^{1.78277} = 33531, \text{ a constant}$$

for these two experiments.

$$\therefore Q = 33531E\left(\frac{h}{l}\right)^{3.78277}. \quad (D)$$

$(l \div h) \begin{cases} > 180 \\ < 240. \end{cases}$

4. Similarly may we find a formula for values of $(l \div h) < 30$.

	No. 19.	No. 21.	Dif. of logs.
log. $(l \div h)$,	1.4672457	0.8651857	0.6020600
" ε	9.9578640	9.0375286	0.9203354

$$\text{Ratio of dif. of logs.} = \frac{.9203354}{.6020600} = 1.52864.$$

$$\therefore \varepsilon\left(\frac{h}{l}\right)^{1.52864} = .00518762, \text{ a constant}$$

for these limits.

Wherefore,

$$\frac{Ql^2}{Eh^2} \times \left(\frac{h}{l}\right)^{1.52864} = .00518762,$$

$$Q = 124503\left(\frac{h}{l}\right)^{.47136}. \quad (C)$$

$(l \div h) < 30$.

5. Also for values of $(l \div h)$ ranging from 30 to 60, we may take

$l \div h$	59.65	30	Dif. of logs.
log. $(l \div h)$,	1.7756104	1.4771213	0.2984891
" ε	0.4143716	0.0496056	0.3647660

$$\text{Ratio of dif. of logs.} = \frac{.3647660}{.2984891} = 1.22204.$$

$$\therefore \varepsilon \times \left(\frac{h}{l}\right)^{1.22204} = .017559, \text{ a constant.}$$

$$Q = 421419\left(\frac{h}{l}\right)^{.77796}. \quad (E)$$

$(l \div h)$, from 30 to 60.

(*See Table II on following page.*)

In the preceding table, under $\frac{h}{t}$, are given the ratios of thickness of metal to least diameter, or of thickness to the mean of the two diameters when h and b are different.

II.—Rectangular Tubular Pillars—Flat Ends.

See Stoney's Theory of Strains, page 271.

Notation as in preceding case. t=thickness of metal.

Gordon's Formula for this case,

$$\frac{P}{S}=Q=\frac{30720}{1+\frac{l^2}{3000\,h^2}}.$$

No.	b ins.	h ins.	$\frac{h}{t}$	$\frac{l}{h}$	$\frac{l}{r}$	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae G, H.	Excess over Q, by Gordon Formula.
1	4.1	4.1	136.6	29.26	71.672	.19596	10,980	+4138	+2310
2	4.1	4.1	68	29.26	71.672	.34373	19,260	− 781	−1503
3	4.25	4.25	51	28.23	69.149	.41807	25,171	0	− 32
4	4.25	4.25	31.7	28.23	69.149	.35837	21,585	+ 288	− 619
5	8.1	4.1	70	29.26	66.452	.35525	23,169	+1756	+2809
6	8.17	4.1	100.6	29.26	66.394	.23268	15,201	− 733	− 248
7	8.4	4.25	32.3	28.23	64.104	.42778	29,981	+1798	+2881
8	8.5	4.75	25.1	25.30	57.906	.31334	26,913	+ 330	+1940
9	8.5	4.75	19	25 30	56.601	.27810	25,000	−2286	−1297
10	4.25	4.25	31.7	21.10	51.684	.21421	23,201	+2522	+5226
11	8.17	4.1	100.6	22.40	50.902	.14588	16,215	− 636	+2079
12	8.1	4.1	69	22.30	50.669	.21538	24,111	+ 323	+3038
13	8.1	8.1	63.6	14.94	36.595	.09176	19,732	+3505	+4994
14	8.1	8.1	135	14.80	36.252	.06058	13,276	− 643	+1709
15	4.1	4.1	136.6	14.60	35.762	.05137	11,513	−1060	+ 35
16	8.1	8.1	63.6	14.57	35.689	.10216	23,100	−2721	−2612
17	8.37	8.37	60	14.33	35.101	.08712	20,364	+2637	+4993
18	8.37	8.37	38.2	14.33	35.101	.11001	25,716	−4529	−3104
19	8.40	8.40	35.7	14.33	35.101	.11413	26,675	−3100	−1826
20	4.25	4.25	50	14.10	34.538	.09793	23,584	+1287	+3550
21	8.1	8.1	135	11.30	27.679	.03589	13,301	− 862	+ 318
22	8.1	4.1	68.3	10.70	24.366	.45123	21,889	−2863	−1595
23	8.1	8.1	63.6	7.40	18.126	.02647	23,208	−6316	−5618
24	4.1	4.1	136.6	7.30	17.881	.01383	12,402	−2334	−2190
25	4 25	4.25	50	7.00	17.146	.02846	27,417	−4680	−4391
26	8.17	4.1	100.6	6.80	15.493	.01327	15,921	+1798	+2678
27	18	18	36	5.33	13.056	.01803	30,464	−1788	− 898
28	8.1	4.1	68.3	4.70	10.798	.01053	26,010	+2331	+ 69
29	8.1	8.1	63.6	3.40	8.328	.00582	24,153	−1619	−1358

$$r^2=\frac{h^3(h+3b)}{12(h+b)}=\frac{h^2}{6},\ \text{when } h=b.$$

In finding a formula for this set of experiments, we consider only those cases where the metal was so thick that $(h\div t)$ is not greater than 55.

Using Nos. 3, 4, and 27, and taking means, we write

	Nos. 3-4.	No. 27.	Dif. of logs.
log. $(l\div r)$,	1.8397859	1.1158101	0.7239758
" ε	9.5890779	8.2559957	1.3330822

$$\text{Ratio of dif. of logs}=\frac{1.3330822}{0.7239758}=1.841335.$$

$$\therefore\ \frac{\varepsilon}{(l\div r)^{1.841335}}=.0001590065\ \text{a constant.}$$

Whence

$$Q=45794\left(\frac{r}{l}\right)^{.158665}. \qquad (G)$$

when $(l\div h)<30$, and $(h\div t)<55$.

But when $(h\div t)$ exceeds 55, we find

$$Q=\frac{55t}{h}\times 45794\left(\frac{r}{l}\right)^{.158665}. \qquad (H)$$

approximately. And this factor has also been applied to the Gordon formula for these cases.

III.—Hollow Cylindrical Pillars—Flat Ends.

See Stoney's Theory of Strains, page 275. h=diameter of pillar. $r^2=\frac{1}{8}h^2$.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	$\frac{h}{t}$	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae I, J, K.	Excess over Q, by Formula L.	Excess over Q, by Gordon Formula.
1	1.495	80	226.274	15	2.6441	14,673	0		−1601
2	1.964	60	172.816	18.8	2.4064	23,206	0	+ 894	−4588
3	2.340	51.28	145.042	10.8	1.6202	22,179	+2443	+2612	− 351
4	2.350	51	144.250	9.7	1.5733	21,572	+3098	+3246	+ 367
5	2.490	47.8	135.199	23.27	1.9357	29,798	−4582	−4666	−6547
6	1.495	40	113.137	15	1.4047	31,180	−4397	−4960	−4466
7	3.000	40	112.877	20	1.2298	27,671	− 867	−1451	− 954
8	1.964	30.5	86.267	18.8	.8693	33,299	−3935	−5420	−2034
9	3.035	29.6	83.721	18	.7430	29,789	− 128	−1709	+1913
10	4.050	29.6	83.721	29	.6745	27,657	+2004	+ 423	+4045
11	4.060	29.6	83.721	26.1	.6373	26,263	+3398	+1817	+5439
12	2.335	25.7	72.690	11.4	.5502	29,998	+1108	− 826	+3571
13	2.350	25.5	72.125	10.6	.5311	29,330	+1858	− 50	+4333
14	2.490	24.1	68.165	23.27	.5700	35,100	−3317	−5956	− 784
15	4.052	22.2	62.791	30.9	.4568	33,331	− 654	−2830	+1850
16	4.000	22.2	62.791	16.5	.3582	26,046	+6631	+4455	+9135
17	4.000	22.2	62.791	16	.3645	26,503	+6174	+3998	+8678
18	4.000	22.2	62.791	16.5	.3825	27,816	+4861	+2685	+7365
19	2.490	21	59.397	23.27	.1482	36,489	−3203	−5465	− 778
20	1.495	20	56.569	15	.3854	34,220	− 375	−2728	+1922
21	6.180	19.4	54.871	65	.3495	33,375	+ 819	−1570	+3019
22	6.360	18.9	53.334	49	.3558	35,985	−1462	−3766	+ 642
23	1.964	15.3	43.275	18.8	.2413	36,980	+ 59	−2609	+1015
24	3.995	15	42.426	16.3	.1881	30,024	+7263	+4577	+8078
25	3.995	15	42.426	16.5	.2159	34,453	+2824	+ 148	+3649
26	6.366	14.1	39.881	48.9	.2313	41,664	−3593	−6336	−3249
27	2.343	12.8	36.204	11.1	.1752	38,214	+1117	−1256	+ 625
28	2.335	12.8	36.204	11.4	.1680	36,639	+2638	+ 319	+2146
29	2.335	12.8	36.204	11.4	.1623	35,389	+3942	+1569	+3450
30	2.383	12.5	35.355	9.7	.1468	33,107	+6522	+3686	+5825
31	2.343	12.3	34.790	11.6	.1684	39,569	+ 292	−2565	− 576
32	2.373	12.2	34.507	10.27	.1531	36,906	+3066	+ 187	+2125
33	6.175	9.7	28.075	61.1	.1006	38,355	+4491	− 173	+1360
34	3.000	9.3	26.305	19.6	.0905	37,392	+6403	+3105	+2420
35	4.000	7	19.799	16	.0651	47,844	+ 347	−4167	−7183
36	4.026	6.95	19.657	16	.0653	48,576	− 268	−4832	−8265
37	6.125	4.9	13.859	62.5	.0276.	41,361	+12779	+3555	− 681

The Gordon Formula here is, $Q=\frac{40960}{1+\frac{l^2}{3000h^2}}$.

1. Using the mean values of ε and of $(l\div r)$ in Nos. 35, 36, and Nos. 8, 9, 10, 11, we write,

$(l\div r)$	84.358	19.728	
ε	0.7310	0.0652	Dif. of logs.
log. $(l\div r)$	1.9261263	1.2950831	0 6310432
" ε	9.8639174	8.8142476	1.0496698

Ratio of dif. of logs. $=\frac{1.0496698}{0.6310432}=1.6634$.

$\therefore \varepsilon\times\left(\frac{r}{l}\right)^{1.6634}=.00045711$, a constant.

$$Q=131648\left(\frac{r}{l}\right)^{.3366}. \qquad (I)$$

when $(l\div h)<30$.

2. Similarly, from Nos. 2 and 8, 9, 10, 11, we find, when

$(l\div h)$ $\begin{cases}>30\\<60,\end{cases}$

$$Q=132807\left(\frac{r}{l}\right)^{.3396} \qquad (J)$$

3. And from 1 and 2 we derive in the same manner,

$$Q=11438000\left(\frac{r}{l}\right)^{1.65043}. \qquad (K)$$

$(l\div h)$ from 60 to 80.

4. We may in all these cases, of course, find values of ε by interpolation, and thence derive Q from the equation

$$\varepsilon=\frac{Ql^2}{12Er^2},$$

or Q may be derived directly by interpolation.

For the case of hollow cylinders, $(l\div h)$ being not greater than 60, we get an approximate formula involving only second differences, by the following arrangement:

$l\div h$	ε	D_1	D_2
10	.11		
		.24	
20	.35		.11
		.35	
30	.70		.11
		.46	
40	1.16		.11
		.57	
50	1.73		.11
		.68	
60	2.41		

From which, by the "method of differences,"

$$\varepsilon=.11+.24(n-1)+.11\frac{(n-1)(n-2)}{2},$$

$$n=\frac{l}{10h},$$

$$\therefore\ Q=12E\varepsilon\left(\frac{r}{l}\right)^2=36{,}000{,}000\varepsilon\left(\frac{h}{l}\right)^2. \quad (L)$$

Mean value of E=27,311,111.

Gordon formula here is

$$Q=\frac{50800}{1+\frac{l^2}{3000h^2}}$$

using the mean of the experimental values of the numerator.

To find formula M we have from

Nos. 29, 28, 10, $l\div r=111.067$, $\varepsilon=1.28803$

No. 6, $l\div r=61.609$, $\varepsilon=.43430$

log. $(l\div r)$, 2.0455851 1.7896453 0.2559398=dif.

" ε 0.1099260 9.6378014 0.4721246=dif.

Ratio of dif. of logs. $=\frac{0.4721246}{0.2559398}=1.84467.$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.84467}=.000217018, \text{ a constant.}$$

$$Q=71124\left(\frac{r}{l}\right)^{.15533} \quad (M)$$

$(l\div h)$ from 20 to 40.

IV.—The "Phoenix Column"—Flat Ends.

See Thomas D. Lovett's Report.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula M.	Excess over Q, by Gordon Formula.
29	8.250	40.7	112.4	8.935	1.4111	36,600	−2444	−3872
28	8.250	40.7	112.4	8.935	1.3417	34,800	− 644	−2072
10	8.125	39.9	108.4	8.935	1.1113	31,000	+3350	+7874
6	8.050	22.4	61.6	8.536	.4343	37,500	0	+6021

V.—The "American Bridge Co.'s Column"—Flat Ends.

See Lovett's Report.

Two flanged bars riveted to the flanges of an I-beam.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula N.	Excess over Q, by Gordon Formula.
15	8	45	155.1	5.388	1.7394	23,700	0	− 655
19	9.5	34.1	88.1	13.510	.6591	27,800	+1353	+ 18
18	9.5	25.3	81.6	8.653	.6398	31,500	−1609	+ 312

Using the mean value of f for the numerator, the Gordon formula becomes,

$$Q=\frac{38600}{1+\frac{l^2}{3000\,h^2}}.$$

We find formula (N), by taking mean values of $(l\div r)$ and ε in Nos. 18, 19, and combining with No. 15.

$(l\div r)$	155.1	84.85
ε	1.7394	.64945

$$\frac{\log.\ 1.7394-\log.\ .64945}{\log.\ 155.1\ -\log.\ 84.85}=1.63346$$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.63346}=.00045937,\text{ a constant.}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.63346}=\frac{Q}{12E}\left(\frac{l}{r}\right)^{.36654}$$

$$Q=150552\left(\frac{r}{l}\right)^{.36654}\qquad(N)$$

$(l\div h)$ from 25 to 45.

VI.—The "Keystone Column"—Flat Ends.

See Lovett's Report.

No.	$\frac{l}{h}$	h ins.	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formulae O, P.	Excess over Q, by Gordon Formula.
27	37.6	8.625	103.5	9.798	.9088	27,800	−2564	−3177
4	35.2	9.2	98.2	10.883	.7093	24,100	+1699	+1720
26	34.6	9.375	96.9	11.178	.7880	27,500	−1556	−1607
25	33.7	9.625	95.8	11.424	.5916	21,100	+4963	+5179
30	34.1	9.5	95.8	11.464	.8411	30,000	−3937	−3899
31	34.1	9.5	95.8	11.464	.7122	25,400	+ 663	+ 701
24	34.1	9.5	93.4	12.041	.6650	25,000	+1353	+1101
9	20.3	8.85	64.3	7.833	.4039	32,000	− 69	− 151
7	21.7	8.3	59.3	9.206	.3222	30,000	+2035	+1312
8	20	9	55.9	10.353	.3524	36,900	−4790	−4936
3	19.5	9.25	54.7	10.834	.2628	28,800	+3339	+3350
2	6.5	9.3	18.054	11.044	.0334	33,600	0	+2122

Gordon Formula, $Q=\frac{36225}{1+\frac{l^2}{3000\,h^2}}$,

using the mean value of f.

1. To find formula (O), use mean values of $(l\div r)$ and ε in Nos. 27, 4, 26, 25, 30, 31 and 24, and in Nos. 9, 7, 8, 3.

Then $(l\div r)=$ 97.06 58.55

$\varepsilon=$ .74514 .33532

$$\frac{\log.\ .74514-\log.\ .33532}{\log.\ 97.06-\log.\ 58.55}=1.5798.$$

$$\therefore\ \varepsilon\left\{\frac{r}{l}\right\}^{1.5798}=.000540995,\text{ a constant,}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.5798},$$

$$Q=177301\left(\frac{r}{l}\right)^{.4202}\qquad(O)$$

$(l\div h)$ from 20 to 40.

2. Similarly, from Nos. 9, 7, 8 and 3, and No. 2, we find

$(l\div r)=$ 58.55 18.054

$\varepsilon=$ .33532 .0334

$$\frac{\log.\ .33532-\log.\ .0334}{\log.\ 58.55-\log.\ 18.054}=1.96.$$

$$\therefore\ \varepsilon\left(\frac{r}{l}\right)^{1.96}=.000115087,\text{ a constant,}$$

$$=\frac{Ql^2}{12Er^2}\times\left(\frac{r}{l}\right)^{1.96},$$

$$Q=37718\left(\frac{r}{l}\right)^{.04}\qquad(P)$$

$(l\div h)$ <25.

(*See Table VII on following page.*)

The Gordon formula here becomes,

$$Q=\frac{44400}{1+\frac{l^2}{3000\,h^2}}.$$

Formula (R) is found as follows:

	No. 22.	No. 23.
$(l\div r)=$	102.050	84.458
$\varepsilon=$	.9533	.7226

VII.—The "Square Column"—Flat Ends.

See Lovett's Report. Two Channels and Two Plates.

No.	h ins.	$\frac{l}{h}$	$\frac{l}{r}$	r^2 ins.	$\varepsilon=\frac{Ql^2}{12Er^2}$	Q by experiment.	Excess over Q, by Formula R.	Excess over Q, by Gordon Formula.
22	7.5	41.6	102.050	9.347	.9533	30,000	0	−1842
32	9.25	30.9	98.096	10.909	.8867	30,200	+ 441	+3480
23	8.43	34.1	84.458	11.628	.7226	33,200	0	−1202

VIII.—Pillars with Rounded or Hinged Ends.

See Lovett's Report.

No.	Kind.	h ins.	l ins.	r^2 ins.	$\frac{E}{100000}$	Q by experiment.	Excess over Q, by Formula A.	Excess over Q, by Gordon Formula.
16	American	8	240	5.479	289	26,700	− 309	−1927
17	"	10	240	8.733	231	26,500	+7122	+2371
13	"	10.75	312	8.733	304	24,000	+2301	−1602
14	"	10	312	8.733	260	22,000	+ 392	+2223
11	Phoenix	8.125	324	8.935	271	21,700	+ 444	−2315
5	Keystone	9.22	324	10.945	295	22,000	+7527	− 61
21	Square	10	309	11.000	310	25,500	+8785	−1087

$$\frac{\log. .9533-\log. .7226}{\log. 102.050-\log. 84.458}=1.46437.$$

$$\therefore \varepsilon \left\{\frac{r}{l}\right\}^{1.46437}=\frac{Ql^2}{12Er^2}\times\left\{\frac{r}{l}\right\}^{1.46437}$$

$$=.00109037, \text{ a constant.}$$

$$\text{Whence } Q=357350\left(\frac{r}{l}\right)^{.53563}. \quad (R)$$

$(l\div h)$ from 25 to 30.

Gordon formula here,

$$Q=\frac{39957}{1+\frac{l^2}{1500h^2}}.$$

It will be noticed that formula (A), viz.

$$Q=9.6E\left(\frac{r}{l}\right)^2,$$

gives, in general, the values of Q too large; and hence it is, in these cases, nearer the truth than the formula above cited as given by Weisbach, Rankine, and Price.

Experiments, however, are wanting, from which to derive complete formulae for pillars.

It is evident that the method here applied to wrought iron pillars, is equally applicable to pillars, struts, or columns, of any other material.

Sharpening Files.—Mr. B. C. Tilghman has recently discovered another and very interesting application of the sand-blast to industrial purposes. He has found that by subjecting worn files to the action of the jet, the cutting edges are rapidly renewed, and the file is made sharper than when new. A stream of fine sand, impelled at a high velocity by a jet of steam, is applied to a file at an angle of from ten to fifteen degrees from its face, the file being moved about so that all parts may be acted on. The sand is very fine grit, prepared by washing and settling. It is used in the state of very soft slime, drawn from a receiver.—*Engineering.*

THE VENTILATION OF COAL MINES.

By GEORGE G. ANDRE.

Transactions of the Society of Engineers.

THE late coal panic has shown us to what degree our material prosperity is dependent on that mineral. It would seem, indeed, that the exhaustion of our coal fields must inevitably be followed by the utter collapse of those industries which have made this country what it is, and that even a slightly decreased production would seriously affect their position. Coal having assumed a relation of such vital importance to our social existence, its extraction from the earth has become one of the foremost engineering questions of the day, and accordingly increased attention is now being directed to it. The author of the present paper has therefore deemed the time opportune for a discussion of some of the facts relating to what is certainly one of the most important subjects of mine engineering, namely, the ventilation of the workings. One of the effects of the recent panic may be seen in the greater activity shown at existing collieries as well as in the opening out of many new ones. In their haste to extract the valuable mineral there is danger that managers and engineers may not give due attention to those matters which are essential to an efficient ventilation, especially in the laying out of new works. Hence another reason for calling attention to the subject at this time. Moreover it is almost an indisputable fact that 90 per cent. of those disastrous explosions which so frequently occur are wholly due to a defective ventilation. Thus it appears that though the principles of a good ventilation are generally understood and acknowledged in theory, they are still far from being applied in practice. By the expression "defective ventilation," it is not intended to mean merely insufficient ventilation, but also all systems of ventilating a mine that are established upon false principles, quite irrespective of the quantity of air passing through it in a given time. Of course it is quite impossible to treat so large a subject in a paper like the present, and therefore no such attempt will be made. All that the author proposes to do is to direct attention to a few essential points, and instead of adducing anything new, to simplify what is already known.

It is agreed on all hands, and Parliament has recently enacted, that a sufficient quantity of air should be constantly passed through a mine to dilute and render harmless the noxious gases evolved or generated therein. But there does not appear to be any definite understanding among mining men as to what constitutes a sufficient quantity, and the practice among careful men is to pass an excess of air in order to be on the safe side. No doubt this is erring in the right direction; but it is better not to err at all. Besides, such a practice begets a vagueness of notion concerning the requisite quantity of air that conduces neither to correctness of judgment nor to progress in knowledge. It may in some cases be a source of danger even, for a Davy lamp is not safe in a violent current of air that has been suddenly fouled by a blower, while the cost of producing the current is enormously increased. Of course the question is an intricate and a difficult one, depending upon numerous conditions that vary from district to district, and even from mine to mine. A general solution is therefore not to be looked for; but it is both practicable and highly desirable to lay down some definite and invariable basis upon which every individual case may be accurately and readily calculated.

The atmosphere of a coal mine is vitiated by several causes: the breath of men and horses, the combustion of lights, the moisture of the ground, the exhalation of gases from the strata, and the chemical changes which are constantly going on in the substances exposed to the influence of the air. Some of these causes are constant in their action or nearly so, while others are extremely variable. The former we can estimate with accuracy; with the latter we can deal only approximately.

The average quantity of air breathed by man is usually assumed by writers

on mine ventilation to be 800 cubic feet per minute. This quantity is, however, altogether erroneous as a basis on which to calculate an adequate amount of ventilation. It has been stated by eminent medical authorities that the mean of several hundred experiments conducted with great care by means of very accurate instruments was 502 cubic inches per minute, and that this quantity was increased to 1500 cubic inches, or nearly three times as much, by the exertion of walking four miles an hour. We all know from experience that a much larger quantity of air is breathed when undergoing violent exercise than when at rest; and we cannot therefore found a calculation relating to men subjected to great physical exertion in a mine upon what has been ascertained respecting a man lying motionless on his bed. It may be assumed that the average amount of labor undergone by each man and boy in the extraction of coal is at least equal to that of walking four miles an hour; and hence the quantity of air required for each man will be 1500 cubic inches, or say, one cubic foot per minute. The miasmata or effluvia derived from the various secretions of the body are a potent cause of vitiation in the atmosphere. The unpleasant smell of a close bedroom in the morning is due wholly to this cause, and in ascertaining the state of ventilation in a room by what is known as the "nose test," it is these effluvia which furnish the requisite indications. Moreover the air in passing over the human body becomes heated. These causes are greatly increased in intensity by the augmented temperature due to violent exertion, such as is undergone in mines. Added to this there is the dust caused by each workman floating in the atmosphere. We must therefore provide an additional quantity of air to keep the atmosphere pure and cool, and this quantity may be taken as one cubic foot per minute. This allows a covering or film of air over his whole body about $\frac{3}{4}$ inch thick, which film is changed every minute. Each man's lamp will heat the air and foul it with the products of combustion to a degree requiring about one cubic foot per minute. Thus the quantity of air requisite per man will be three cubic feet per minute. A horse fouls about six times as much as a man, and will therefore require twelve cubic feet per minute.

The foregoing may be considered the constant causes of vitiated air, and are easily dealt with. We come now to consider the varying causes, namely, the moisture of the ground and the gases evolved. It is impossible to treat these otherwise than approximately, but an approximation sufficiently near for practical purposes may be arrived at. The gases existing in a coal mine are chiefly carbonic acid or choke-damp and carburetted hydrogen or fire-damp. Other gases are generated, but in such small quantities that their presence is not of much importance, except perhaps when blasting is extensively practiced. These two gases, carbonic acid and carburetted hydrogen, are continually being exhaled in greater or less quantities from the face of the exposed strata, and therefore the total quantity is to a certain degree dependent on the extent of surface exposed. They are given off more abundantly from fissures, especially in the neighborhood of faults. Considerable quantities of carbonic acid are also in every mine due to the respiration of men and horses, the combustion of lights and the deflagration of gunpowder, all of which causes are subjects of calculation. In smaller quantities, carbonic acid is formed by the fermentation and decomposition of vegetable matter.

When the proportion of carbonic acid to the atmospheric air reaches $\frac{1}{10}$th the compound will not support combustion, and is fatal to life. A proportion of $\frac{1}{15}$th of carburetted hydrogen renders the compound inflammable. These proportions may be taken as the limits which must never be reached; or, to further simplify the matter, the proportion of pure atmospheric air must, in a mine, never be less than $\frac{14}{15}$ths of the total volume therein contained.

The question now is what quantity of air in a dry mine, making but little gas of any kind, is sufficient, irrespective of the respiration of men and horses, to ensure this proportion under all conditions. This problem, as we have said, can only be solved approximately, but as it is mainly a matter of experience and calculation, a fairly close approximation may be arrived at. A careful investigation of this matter has led the author to con-

clude that one cubic foot of air per second for every 100 square yards of surface is an adequate quantity. This allows for the exhalation and formation of .067 cubic foot of impurities, that is, noxious gases, watery vapor, and solid floating matter per second. In other words, one cubic foot of air per 100 yards of surface is equivalent to a film about $\frac{3}{4}$ inch thick spread over that surface, which film is changed every minute. And .067 cubic foot of gases to the same extent of surface is equivalent to a film about $\frac{1}{15}$ inch thick formed every minute. Of course the gas is not exhaled in this regular way over the whole surface exposed. But the quantity here given is approximately that which is given off the surface at the worst parts under the conditions previously mentioned.

This quantity of one cubic foot per second for every 100 yards of surface may be taken as a reliable basis upon which to calculate an adequate ventilation. It must be borne in mind that the quantity is only just sufficient under the very favorable conditions which we have assumed, and is, therefore, analogous to the breaking strain of materials. In every case it will have to be multiplied by an appropriate factor of safety, the value of which must be determined by the conditions of the case. All mines are, in a greater or less degree, liable to give off "blowers," that is pent-up accumulations of gas which are liberated by the boring and driving, or by falls of roof. The gas issues from the blowers with a sound resembling, in the smaller ones, the simmering of a teakettle, and in the larger that of blowing off high-pressure steam. Of course it is quite impossible to estimate the value of these blowers with anything like accuracy, just as it is impossible to estimate the value of the strain to which a structure exposed to sudden shocks may be subjected. In both cases a sufficiently large factor of safety must be taken to include possibilities and to leave an ample margin of safety. It may be remarked that no system of ventilation can be calculated for the large blowers previously mentioned. They are fortunately of rare occurrence, and when one does occur, the only practicable plan is to call out the men until it has exhausted itself. When their presence is suspected, safety lamps alone should be used. The small blowers are more constant in their action, and are capable of being estimated with some degree of precision..

Besides varying in gaseous products, mines differ in degree of moisture. Blasting is also more extensively practised in some mines than in others. All of these circumstances will influence the factor of safety, the value of which must be determined for every individual case, and which will vary from 2 to 6. Let us now apply these principles to an example. Suppose we have to ventilate a mine in which the air-courses have a total length of 2000 yards, giving a total surface of, say, 14,000 square yards; and, to simplify the calculation, we will suppose that the number of men and horses are 100 and 10 respectively. Respiration, perspiration, and lamps will then require $100 \times 3 + 10 \times 12 = 420$ cubic feet per minute; and the gases, vapors, &c., will need $\frac{14000}{100} = 140$ cubic feet per second = 8400 cubic feet per minute. Supposing the mine to generate but little fire-damp and to be not particularly wet, we may take the factor of safety at 3, which will give $(840^{\circ} + 420) \times 3 = 26{,}460$ cubic feet per minute as the adequate amount of ventilation. In this case we have taken the surface and the factor of safety for the entire mine; but when, as it usually is, the mine is divided into several districts, which are aired by separate currents, the air must be apportioned according to the surface of each district and the factor of safety determined by the nature of the seam or the conditions of the workings. Thus the factor of safety may vary from district to district.

When the proper quantity of air has been determined, the next question is, how to get it through the workings. One mode of effecting this is to provide contracted air-ways and to give the ventilating current a high velocity. Another is to have spacious air-ways and a low velocity. For economical reasons, the former is but too frequently adopted. In many cases a drift is driven with an insufficient sectional area; in other cases, falls of roof, the creep of the floor, and other causes reduce the dimensions of an air-passage to those of a mere creeping hole. Fully 25 per cent. of the air-

courses in collieries which are now being worked, and in which the ventilation is said to be perfect, can only be entered by a man in a crawling posture. The economy of a system that lays out works in such a manner, or that allows them to get into such a condition, is more than doubtful. The drag of the air, that is, its retardation by contraction and friction, is enormously increased thereby, and the consumption of fuel in the furnace, or in the engine when a mechanical ventilator is used, is augmented in a like proportion. But even when the additional cost of fuel is incurred; the friction with small passages and high velocities is so great that it is impossible to ensure sufficient ventilation at all times, and hence there is the constant risk of accident, with its accompanying danger to life and property. It may therefore be laid down as one of the essential principles of an efficient ventilation, that spacious air-ways are indispensable. A limit that may be adopted with advantage is, that all air-ways other than shafts should allow a sufficient quantity of air to pass with a velocity not exceeding 6 feet per second.

Another important fact connected with the dimensions of air-ways is, that the return passages require a larger sectional area than the intake passages. When the ventilating current enters the return ways from passing through the workings, it is laden with the various gases that are generated in a mine, watery vapor, the solid products of combustion and coal dust, and its temperature, and consequently its bulk, is considerably increased. Thus it has lost a great part of its elasticity and it drags more heavily. To compensate this, its friction should be lessened by increasing the sectional area of the passage. To ensure a proper state of ventilation there should be two return ways, each equal in sectional area to the intake. As far as practicable, the air-courses should have at all parts of their length the same sectional area. It is, perhaps, hardly necessary to remark that they should be kept free from all obstructions, such as projecting pieces of timber or stones.

One of the most effective means of diminishing the friction is to shorten the runs by dividing the workings into districts and ventilating each with a separate air-current. Thus, a shaft 12 feet in diameter will afford sufficient area for five different air-ways each of 20 feet area. This system of splitting the air, as it is called, though well-known, is not adopted so extensively as it ought to be. There are many mines in which the old unwholesome and dangerous practice of passing the air through in one column from the downcast to the upcast shaft still prevails, though the evils attending it have long been acknowledged by the majority of viewers. An additional and great advantage possessed by the system of ventilating by districts is that of confining the effects of an explosion to a small part of the workings. In all cases of splitting the air, the split should be made as near the downcast shaft, and the several branches reunited as near the upcast as possible, and the air-ways between the shafts and the points where the branches separate and reunite should have a large sectional area.

The distribution of the air through the workings requires great skill. There are, indeed, few matters connected with mining that test the skill and ability of the engineer more than this. A very slight variation in the direction of the ventilating current may make all the difference between a good and a defective, and consequently a dangerous ventilation. And yet this important duty is often left to ignorant hands. No doubt the men who are entrusted with this important work are experienced men, and men who on that account would be called practical. But there are things which experience alone cannot teach, at least in the lifetime of a single individual. A certain amount of scientific knowledge and an acquaintance with collateral subjects, such as the composition of gases, the nature of fluids, and the laws which they obey, are absolutely necessary to enable a man to manage efficiently the ventilation of a mine. And such knowledge is part of a liberal education.

The essential conditions of a good distribution are: (1) That the air shall not pass from the broken to the whole workings; and (2) that an explosion shall not take the air off the men at the faces of work, or reverse its direction.

The author does not hesitate to assert that three-fourths of the explosions that occur, and that result in such a lamenta-

ble destruction of life and property, are caused solely by the neglect of the former of these conditions, and are therefore preventable; and that a large proportion of the deaths that result are due to the neglect of the latter conditions; for in most cases fewer men are killed by the direct effects of the explosion than by the after-damp. It does, indeed, seem strange that such an ignorant mode of distributing the air should still be commonly adopted. When the ventilation is in uneducated hands we may attribute the practice of the pernicious system to ignorance and want of skill; but when, as is sometimes the case, we find the practice perpetuated under the authority of men eminent in their profession, we are forced to believe that a criminal economy is at the bottom of the matter.

The second condition is scarcely of less importance than the first, as it deals with the effects of an explosion should such an accident occur from any unforeseen cause. The ventilating current will always take the shortest course to the upcast shaft. If, in consequence of an explosion, the doors or stoppings are injured, a large portion of the workings may be left entirely without air at a time when it is most needed, namely, when the passages are foul with the after-damp or carbonic acid gas produced by the explosion. To prevent such an occurrence the distribution should be so arranged as to preclude the possibility of the current of air being diverted from its proper course before it has left the working places, or of being stopped altogether by an injury to the return passage. All permanent stoppings should be built of brick or stone and well plastered; they should also be well backed, especially those by the side of the main ways, which should have five or six yards of stowing behind them. Whenever a crossing is necessary for the return it should, if possible, be by a stone drift over or under the main way. The additional cost thus incurred would be more than compensated by the additional security obtained. Were all these precautions duly observed, mining would be freed of half its perils. A strict supervision would be all that was necessary to protect the mine against the danger of an explosion occasioned by any but unforeseen causes. Such supervision is indispensable in all cases to ensure the proper quantities of air being apportioned to the several districts, and the needful precautions constantly taken to maintain a steady uniform current of air. Without this the best system must prove ineffectual.

DISCUSSION.

Mr. Baldwin Latham said he would offer a few remarks in order to open the discussion, but his observations would be on the general question of ventilation rather than with particular reference to coal mines. He had certainly given some attention to the ventilation of coal mines when studying the ventilation of sewers; but he had found that the system of having one downcast and one upcast shaft for the ventilation of coal mines was comparatively easy to carry out, but that it was not at all applicable to sewers. From his examination of a large number of coal mines he was convinced that the observations which had been made by Mr. André in his paper were of very great value. The paper did not touch upon the particular means which were adopted for the ventilation of coal mines, but it simply brought forward broad facts which it would be well for all interested in such matters to bear in mind, and which showed that there never could be safety without a superabundance of fresh air. There was not sufficient attention paid to the ventilation of a mine as the workings were worked out, or as the material was extracted. In his opinion a new mine required far less air than one which had long been at work. The little passages which were shown in the diagrams were air-channels; and in a new mine the cubic capacity of those channels would be comparatively small; but when the mine was worked out the cubic capacity became greater. When gases escaped or blowers occurred, the passages and goaves acted as gas-holders by means of which gas could be accumulated. In an old mine the same intake and the same volume of air passed through it as in a new mine, although the cubical capacity in the old mine was greater. The chances were that in old mines the whole area might become occupied with gas which, by the admixture of the atmospheric air, in limited quantities, would be rendered explosive.

Instead of being diminished as the mine was worked out, and the cubical capacity of the mine became greater, the amount of air ought to be increased, and not only so, but adequate mechanical arrangements ought to be introduced by which the air could be conducted through the vacant spaces so as to completely ventilate the mine.

It was a disputed point whether natural or mechanical means ought to be adopted for ventilating mines. By mechanical means, he meant the use of steam as a mechanical power, for either driving air into the mine or sucking air out. The plan of driving air into a mine was called the plenum system, and the plan of drawing air out was called the vacuum system. The natural system of ventilation consisted of those methods in which the air of a mine was heated by ordinary combustion, so that they got a column of heated atmospheric air which was considerably lighter than an equal column of cooler air, and by this difference in the weight of respective columns of air motion was produced. Air upon being heated dilated $\frac{1}{480}$th of its own bulk for every degree Fahrenheit. Hence he fully corroborated the statements of Mr. André, that the passage for the exhausted air required to be far larger than the passage for the intake air. Air always passed into a mine at a temperature far lower than that of the air some hundreds of yards below the surface of the earth. The air of a furnace was applied in order to heat air in excess of atmospheric heat, and create that current of air which is necessary to aerate every part of the mine. A cubic foot of air heated 50 or 60 or perhaps 80 degrees would occupy a far larger space than it originally occupied when it entered the mine. This caused the necessity for increasing the size of the air-passage for all air which had once passed through the mine. If this was not done there would be a contraction, and contraction meant waste of force, and it also meant retardation of ventilation. Further, it was possible when there was a contracted passage that from some sudden cause, such as the explosion of gunpowder in the mine, the whole current of ventilation might be changed in the opposite direction. Therefore it was needful in all cases of mine ventilation to make the passage of the air as easy as possible, from the place where it entered to the place where it passed out. If the passages were uniform throughout, some circumstances might momentarily change the direction of the air, and the result to those who were laboring in the mine might be an immense loss of life. Hence the necessity of producing enlarged passages for the easy exit of the air that had been used in the mine. Air would always take the shortest passage. We might make passages for it, but it would not follow the route prescribed for it if it could get away by any shorter cut.

THE DISTRIBUTION OF AMMONIA.*

By Dr. R. ANGUS SMITH, F. R. S., &c.

From "Journal of the Society of Arts."

If organic matter is everywhere, ammonia is everywhere possible, and if that matter is decomposing, ammonia is everywhere. This is the general statement which this paper illustrates. It is now many years since it was observed by me that organic matter could be found on surfaces exposed to exhalations from human beings; but it is not till now that the full significance of the fact has shone on me, and the practical results that may be drawn from it in hygiene and meteorology. These results are the great extension of the idea that ammonia may be an index of decayed matter; the idea itself has been used partly and to a large extent, as illustrated in my "Air and Rain." The facts now to be given enable us to claim for it a still more important place. The application seems to fit well the conditions already examined, and by this means currents from fou

* Paper read before the Manchester Literary and Philosophical Society.

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places have been readily found. This does not apply to the substances which may be called germs, whether it be possible to see them or not, because these are not bodies which have passed into the ammoniacal stage, although some of them may be passing; those, for example, which are purely chemical, and exert what we may call idiolytic action. This word may serve to mark this peculiar action, which was left by Liebig unnamed; he used the vague term invented by Berzelius, namely, catalytic. I have elsewhere recognized the two classes of germs, instead of any disputed one, without naming them.

It is now many years since Liebig first surprised me by saying that iron ores and aluminous earths were capable of taking up ammonia, and if they were breathed upon we were able even to smell that substance. He, much about the same time, made numerous experiments, in order to find the ammonia of the atmosphere, and to measure its amount in rain. The result for science was great, and Professor Way continued the inquiry for the Royal Agricultural Society. Dr. Gilbert, F.R.S., amongst his many labors in the department of agricultural science, has made this inquiry into ammonia of rain in still later times; but I shall not at present quote his results, as this paper does not intend to go fully into the subject, but rather to indicate its magnitude and importance. The first paper I ever read to this Society was on the ammonia found in peat: I was unable then to see the extent of the subject.

I shall give parts of the fuller paper without the long tables of results.

Ammonia must ever be one of the most interesting of chemical compounds. It comes from all living organisms, and is equally necessary to build them up. To do this, it must be wherever plants or animals grow or decay. As it is volatile, some of it is launched into the air on its escape from combination, and in the air it is always found. As it is soluble in water, it is found wherever we find water, on the surface of the earth or in the air, and probably in all natural waters, even the deepest and most purified. As a part of the atmosphere it touches all substances, and can be found on many; it is, in reality, universally on the surface of the earth, in the presence of men and animals, perhaps attached, more or less, to all objects, but especially to all found within human habitations, and, we might also add, with equal certainty, the habitations of all animals.

If you pick up a stone in a city, and wash off the matter on the surface, you will find the water to contain ammonia. If you wash a chair, or a table, or anything in a room, you will find ammonia in the washing; and if you wash your hands, you will find the same; and your paper, your pen, your table-cloth, and clothes, all show ammonia, and even the glass cover to an ornament has retained some on its surface. You will find it not to be a permanent part of the glass, because you require only to wash with pure water once or twice, and you will obtain a washing which contains no ammonia. It is only superficial.

This ammonia on the surface is partly the result of the decomposition of organic matter continually taking place, and adhering to everything in dwellings. The presence of organic matter is easily accounted for, but it is less easily detected than ammonia. It is probable that the chief cause of the presence of ammonia on surfaces in houses, and near habitations, is the direct decomposition of organic matter on the spot. If so, its presence, being more readily observed than organic matter itself, may be taken as a test, and the amount will be a measure of impurity. A room that has a smell indicating recent residence will, in a certain time, have its objects covered with organic matter, and this will be indicated by ammonia on the surface of objects. After some preliminary trials, seeing this remarkable constancy of comparative results and the beautiful gradations of amount, it occurred to me that the same substance must be found on all objects around us, whether in a town or not; I, therefore, went a mile from the outskirts of Manchester, and examined the objects on the way. Stones that not twenty hours before had been washed by rain showed ammonia. It is true that the rain of Manchester contains it also; but, considering that only a thin layer would be evaporated from these stones, it was remarkable that they indicated the existence of any. The surface of wood was examined—palings, railings, branches

of trees, grass (not very green at the time), all showed ammonia in no very small quantities. It seemed as if the whole visible surface around had ammonia. I went into the house and examined the surfaces in rooms empty and inhabited, tables, chairs, ornaments, plates, glasses, and drawing-room ornaments. A (Parian) porcelain statuette, under a glass, showed some ammonia; a candlestick of the same material (but uncovered) showed much more; the back of a chair showed ammonia, when rubbed with a common duster, very little. It seemed clear that ammonia stuck to everything.

If, then, ammonia were everywhere, the conclusion seemed to be that it was not at all necessary to do as I had been doing, namely, wash the air so laboriously; it would be quite sufficient to suspend a piece of glass, and allow the ammonia to settle upon it. For this purpose small flasks were hung in various parts of the laboratory, and they were examined daily. The flasks would hold about six ounces of liquid, but they were empty, and the outer surface was washed with pure water by means of a spray bottle; it was done rapidly, and not above 20 c.c. (two-thirds of an ounce) of water was used. This was tested for ammonia at once with the Nessler solution. The second washing produced no appearance of ammonia, done immediately. Ammonia could be observed after an hour and a half's exposure, at any rate, but I do not know the shortest period. The results of the washings were as follows; they are the average of 34 experiments for some, and 17 for others; in all 238 experiments:

	Height from floor.		Ammonia	Height from floor.		Ammonia
	ft.	in.	M.gms	ft.	in.	M.gms
Front laboratory.	7	3	0.013	4	2	0.019
Second landing..	6	0	0.032			
Balance-room....	5	1	0.015	0	8	0.009
First landing....	4	10	0.007			
Back laboratory.	4	5	0.010	0	6	0.010
Entrance lobby..	6	5	0.007			
Office.....	4	7	0.003			
Back yard.....	4	8	0.036	0	7	0.042
Back closet	2	3	0.105			
Midden.....		—	0.572			

The first three belonging to the working laboratory are not very regular, as we might suppose, but they never rise very high, nor do they sink to the lowest. The rest, except the second, keep a remarkable similarity, and the differences are very great. In the second there is a disturbance caused by sweeping the floors. On the other days it was requested that everything should be kept still. This of course brings in a practical difficulty, and limits the use of the test to cases where care can be used and thoughtful observation, since there are many ways by which dust may be made to interfere, even although the act of sweeping should not take place. The house experiments gave similar gradations.

The result seems to be that a piece of glass, of a definite size, hung up in any place, will receive deposits of ammonia, or substances containing ammonia, in a short time; and by washing the ammonia off with pure water, and testing it with a Nessler solution, it may be seen whether there is too much or not. It is the simplest test for ammonia yet found. Its discoverer deserves great thanks. It must not be forgotten that we may have ammonia in very different conditions; it may be pure, or it may be connected with organic matter. This mode of inquiry is better suited as a negative test to show that ammonia is absent, than to show what is present. When ammonia is present there may be decomposing matter; when absent there is not. I am hoping to make this a ready popular test for air—a test for sewer-gases, for overcrowding, for cleanliness of habitations, and even of furniture, as well as for smoke and all the sources of ammonia. Of course it must be used with consideration, and the conclusions must not be drawn by an ignorant person.

How far it may be used as a test of climate is a matter to be considered.

After this I made another series of trials with air. Nesslerising the washings at once, and not after laborious distillings, as in former cases; the results are very valuable, showing that we obtain comparative quantities in this way.

The amount of ammonia obtained in this ready way does not give exactly the same results as the more laborious methods which I have used, but it may be taken as the most convenient. It must be observed that the amount rises

exactly where you might expect more organic matter to exist. The lowest is from Prince's road, outside the town, and almost half a mile from the extreme of the Manchester houses. The next is obtained from an empty yard behind my laboratory, but it is still pure because there was wind and rain; and any one who observes how unusually pleasant it is to breath air even of a smoky town during wind and rain will not be surprised. I have not yet, however, had the purest air. I shall require to make a campaign on the moors, hills and seas, before I can give numbers for this. I have not even obtained the best given on land at a distance from manufactures. All this will be done in time.

In my office the amount is larger than outside, but the air is not so bad as it is in front, and not so good as sometimes in the front where it is open. From the back of the laboratory, during fog, the ammonia was much higher, but during one day it was excessive, and a special examination of it was made in several streets. The highest amount was obtained at the front of the Cathedral, about midday, on the 8th of February, 1878, when the amount was 1.25, or 14½ times more than it had been found in Prince's Road, showing a considerable range:

	M.grms. of ammonia per cubic meter of air.
Prince's Road	0.086
Open yard during rain	0.119 and 0.102
Front of laboratory	0.167 ordinary
Office	0.167
Front and back during fog.	0.476
Close shut up room	0.413
Closet outside	0.800 to 0.900
Densest part of fog	1.25

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The papers published by the Society in the "Transactions" since our last issue are:

No. 159. On the Theoretical Resistance of Railway Curves, by S. Whitney.

No. 160. On the Cause of the Maximum Velocity of Water Flowing in open Channels being Below the Surface, by James B. Francis.

No. 161. The Flow of Water in Pipes under Pressure, by Charles G. Durragh.

INTERNATIONAL CONGRESS ON CIVIL ENGINEERING.—The programme of the International Congress on Civil Engineering at Paris, in 1878, is of importance not only as a guide to inquiry and discussion, but as a synoptic view of that branch of practical science as regarded in France. It consists of nine sections, which are as follows:

Section 1. *Mines and Metallurgy.*—1. Steel: New Modes of Making Steel; 2. Explosions of Firedamp; 3. Transport in Working Mines; 4. Mechanical Working of Coal; 5. Process of Sinking Wells and Shafts.

Section 2. *Agriculture and Rural Engineering.*—1. Steam Culture; 2. Utilizing Hydraulic Resources; 3. Reclamation of Land fit for Cultivation; 4. Machines serviceable for Harvesting; 5. Economical Transport in Farms.

Section 3. *Machines.*—1. Steam Power; 2. Accumulators; 3. Associations for Supervision of Steam Engines; 4. Unification of the Dimensions of the Parts of Machines; 5. Choice of the Fittest Metals to adopt for the different Parts of Machines.

Section 4. *Roads, Rivers, and Canals.*—1. Inundations: Means of Checking them; 2. New Descriptions of Metal Bridges; 3. Utilization of Roads and Banks for the Establishment of Railways; 4. Comparison of the Different Modes of Paving Towns; 5. Dams for Rivers.

Section 5. *Railways.*—1. Economical Railways; 2. Motor Machines for Tramways; 3. Material Improvements to Introduce into the Passenger Service; 4. Perfecting the Way; 5. Employment of Steep Gradients.

Section 6. *Navigation, Fluvial and Maritime.*—1. Compound Engines in Marine Navigation; 2. Resistance of Hulls; 3. Haulage of Boats: Life-boats; 5. Rolling and Pitching.

Section 7. *Public and Private Constructions.*—1. Supply and Distribution of Water in Towns; 2. Drains; 3. Ventilation of Edifices; 4. Mechanical Perforation of Galleries and Tunnels; 5. Foundations of Great Works.

Section 8. *Industrial Physics and Chemistry.*—1. Utilization of Artificial Cold: 2. Lighting large Workshops; 3. Pneumatic Telegraphs; 4. Industrial Employment of Explosive Substances; 5. Gas Stoves.

Section 9. *Different Industries.*—1. Machines for Domestic Use; 2. Fabrication of Paper, from the point of view of the Paucity of Rags; 3. Recent Progress of Spinning and Weaving; 4. Cements, their Manufacture and Use; 5. Character of Textile Fabrics.

IRON AND STEEL NOTES.

MESSRS. HOOPES & TOWNSEND, manufacturers of iron bolts, nuts, rivets, etc., have issued a pamphlet which contains much valuable information. It is largely made up of reports by Professor Thurston on tests made under his supervision upon cold punched and hot pressed nuts.

The results are beautifully tabulated and the reports are illustrated by cuts of the first order of excellence.

The paper on the flow of metals by Tresca is added with illustrations. This paper explains how in cold punching the strength of the metal is preserved.

The exhibit at the Centennial of this celebrated firm proved the excellence of their method.

IMPROVEMENT IN THE MANUFACTURE OF STEEL.—The following description of an improvement in the manufacture of steel has been sent to the "Bulletin of the American Iron and Steel Association" by Mr. W. Dougherty of Cedar Lake, New Jersey, the patentee. "Steel cast by the ordinary process is rarely free from seams, soft places, honeycomb, &c., thereby causing considerable loss to the manufacturer or purchaser. The object of my invention is the production of steel free from defects. The invention relates to the casting of the ingots in sheet metal moulds or cases of such thickness as will be brought to a welding heat without chilling the surface of the ingots, so that the steel and case may cool and shrink simultaneously, and the case become thereby welded to the steel, and thus exclude the atmosphere from the latter and thereby prevent such imperfections as result from the shrinking away of the steel from the mould. I make the case of any form or size the ingot is required to be, taking care not to have the sheet out of which it was formed of greater thickness than will be brought to a welding heat without cooling the surface of the melted steel when poured into it, so that the case and ingot may cool simultaneously and a complete welding be produced. The sheets of which the cases are formed should not be too thick, otherwise a welding will not take place, and the thickness should vary according to the size of the case; consequently, for casting small bars of steel, say two or three inches in diameter, the thickness should not be more than the sixteen-wire gauge. The steel thus encased when put into the furnace for heating, having its surface completely protected from the atmosphere, retains the carbon in its imperfect places as well as in the solid parts of the metal, and consequently, when subjected to the action of the rolls or hammers, a complete welding of the metal is produced, and a homogeneous mass of the metal is the result. A portion of the metal case or mould is burnt or wasted away during the process of heating the steel. The remainder, being thin, is taken off, or nearly so in the working of the metal, so that no inconvenience results from the steel being encased. In the usual method of casting ingots in thick cast iron moulds the moulds chill the surface of the ingot, causing a deep hole in the upper end, which is technically called piping. This occasions the necessity of breaking off the end of the ingot, and thus causes a loss of from ten to twenty five per centum of the steel. In casting by my process, the mould or case, being thin, does not cool the melted steel, and being brought to a welding heat by the latter, as above specified, the steel cools slowly and uniformly with it closing in to the centre of the ingot, and thus avoiding the piping incidental to the usual mode of casting in thick moulds. I claim as my invention the method of casting steel in wrought iron or other metallic cases when the latter is of such thickness as to admit of the heat of the melted steel completely welding the case to it, substantially as and for the purpose above set forth."

THE PRESERVATION OF IRON SURFACES.—Mr. George Bower, of St. Neot's, has lately perfected a process for coating iron with the magnetic oxide, not however by means of superheated steam, but by the employment of heated air. Mr. Bower conceived the idea that the oxygen as it exists in the atmosphere would serve the same purpose equally as well as, if not better than, the oxygen as it exists in water or steam. He therefore made some elaborate experiments which conclusively proved his supposition to be correct.

Having satisfactorily established this fact Mr. Bower experimented on a large scale, and at length succeeded in giving practical shape to his process. During his experiments Mr. Bower had an idea that the hot blast as used in the production of pig-iron would not only heat iron exposed to it to the required temperature, but that it would at the same time supply the oxygen for the formation of the magnetic oxide. By the courtesy of Messrs. Cochrane, of Dudley, he was enabled to prove this. A bar of iron of square section exposed to the action of the hot blast for about twelve hours was found to be thoroughly coated with the magnetic oxide. This coating, it is stated, has perfectly resisted the oxidising action of moist air under the most trying conditions. The method of procedure in practice is to expose the iron articles in a retort or chamber, the temperature of which is raised to a point dependent upon the ultimate use to which the articles are to be put, and which ranges between a dull and a bright red heat. Air is then introduced and imprisoned in the chamber, a fresh supply being fed in at stated intervals. The articles under treatment are exposed to the combined influence of heat and air for periods which vary according to the nature of the objects, the result being the formation upon them of the protective coating of magnetic oxide.

In carrying out the process at his works Mr. Bower uses an iron chamber which is built into a furnace; it is, in fact, set very much in the same way as gas retorts are. The chamber is about 7 feet long by 2 feet in height and width, and its mouth is closed by a carefully fitting lid having two holes in it. One of these holes serves as an inlet for the air whilst the other is the outlet. The inlet aperture has screwed into it a long tube which reaches nearly to the further end of the chamber. This pipe is connected with an ordinary gas holder filled with air fitted with a tap, as is also the outlet pipe, which is of course very short. The articles to be operated upon are placed in the chamber and the cover is luted and screwed tightly on. The temperature is then raised to the required degree, for ordinary purposes a dull red heat being employed. At the end of every hour a sufficient quantity is driven into the retort to sweep out the deoxidised air, after which the inlet and outlet cocks are again closed. After a certain time which, as we have stated, varies with circumstances, the articles are withdrawn, and are found to have received a perfect coating of oxide. The color of this coating is exceedingly pleasing to the eye being a grey or neutral tint of varying depth, that is to say, ranging between a light and dark shade. Some sam-

ples we have seen possess a very delicate color and one which renders further ornamentation by means of paint quite unnecessary. Notwithstanding this delicacy of tint we are informed that exposure to the influences of atmosphere and weather, and the application of severe tests, have no detrimental effect upon it. The apparatus used by Mr. Bower is at present only experimental, that is, it is not adapted either by size or arrangement for commercially working the process. Having, however, demonstrated its practicability on a reasonably large scale, we presume its adoption on a working basis will soon follow. In such case it is intended that the draught of the shaft leading from the furnaces shall be the agency by which the air will be drawn into the chamber. Moreover, the capacity of the chambers will vary with the size of the articles to be coated, and they will be run into the chambers on tracks so as to admit of their ready removal from, and the quick recharging of the chambers.

We may mention that although Mr. Bower's process answers particularly well for cast iron it is not at present so well suited for wrought iron. Mr. Bower, however, is now working out some slight modifications, by means of which he expects to be able to attain equally satisfactory results with both wrought iron and steel. The cost of thus coating the iron is estimated at about £1. per ton, whether the ton be a solid mass of that weight, or whether the weight be made of a large number of small articles. This estimate, however, may be altered by the light of practice, but provided it is not greatly exceeded, and provided also that the process is as easy of application, and the coating as permanent, as it appears, to be, there is a promising future before Mr. Bower's ingenious process.

RAILWAY NOTES.

ORENBURG AND CENTRAL ASIA.—A Berlin correspondent announces that Russia is making an effort to secure the early construction of the railroad from Orenburg into Central Asia—200 German miles. The money required will be raised by a loan.

VICTORIAN RAILWAYS.—At the close of 1876 Victoria had 702 miles of line open for traffic, and there were further 259 miles in course of construction. Up to December 31, 1876, the expenditure on the Victorian railways, inclusive of rolling stock and plant, was £13,710,364. the approximate average cost per mile was £19,558, which will be reduced to £15,440, when the new lines are finished. The rolling stock comprised 61 passenger engines, 63 goods engines, 210 carriages, and 2,194 wagons, vans, cattle trucks, &c. For the year July 1, 1876, to June 30, 1877, the receipts were £1,074,497. For the previous year they were £994,767.

A HALF-FINISHED RAILWAY.—The Chilian Government has concluded a provisional contract for the completion of the Chili and Southern Railroad, one of the enterprises in which the government was induced to embark some time since. The road, which is 400 miles in length, is in operation, in spite of the fact that no stations have been erected, and that the permanent way has yet to be ballasted. No less than forty rivers lie across the path of the line, while at present only ten bridges have been constructed, those bridges being of wood, which the contractors will not guarantee to stand any lengthened strain. Where there are no bridges the passenger are conveyed across the rivers, and they then re-embark in fresh cars on the other side.

ST. GOTHARD.—The proposal for a supplementary grant in aid of the St. Gothard Railway has been submitted to a popular vote in the canton of Zurich, and has been rejected by a large majority. It is believed that the decided line taken in Zurich will give strength to the growing impatience of seemingly unlimited outlay, which is felt in other cantons, and that not only will the cantonal grants in aid be refused, but the national subvention that has been proposed, will also fall to the ground. In that case the undertaking must be suspended for want of capital, unless the governments of Germany and Italy, which are already pledged to contribute a very large sum, undertake to supply the whole of the deficit. We are afraid, therefore, that the prospects of the completion of the St. Gothard Railway—we do not say by 1880, the date originally fixed, but within any reasonable period—are gradually vanishing. Already large sums have been expended, chiefly upon the construction of the celebrated tunnel between Geschenen and Airolo, but unless a much larger outlay be now faced, all that has been done since 1871 will go for nothing.—*Iron.*

ENGINEERING STRUCTURES.

THE SUEZ CANAL.—The transit revenue of the Suez Canal Company amounted for the first five months of this year to £651,817, showing a reduction of £33,992, as compared with the corresponding period of 1877. This result was attributable to the reduction made in the tolls in April, 1877.

THE NEW EDDYSTONE LIGHTHOUSE.—It is announced that the Trinity Board, after six weeks' consideration, have decided to build the new Eddystone Lighthouse themselves, and not under contract. The estimate of the Board's engineer was £90,000. There were three tenders, the lowest, that of Mr. Pethick, of Plymouth, being £105,000.

The *Western Morning News* gives the following description of the proposed new structure: The first point which offered itself for consideration was obviously that of the precise site for the new work. Smeaton's tower, (the present building) was, of course, erected on the very site of its predecessors—the wooden, or mostly wooden, structure of Rudyerd, which was completely destroyed by fire; and the fantastic building, also of wood, put up by Winstanley, as the first occupant of the rock, and which, together with its author, was utterly annihilated in the great storm of the

26th of November, 1703, after a brief but useful existence of three years.

The "House Rock," as it is called, upon which the present tower is built, stands not alone, but is only one and the highest of a group of rocks and reefs, projecting their jagged summits in the range of tide between low and high water. These comprise the House rock and reef, the South rock and reef, the South-east reef, the East Rock, and a detached spit, the North-east rock. The position selected for the new tower is on the South Reef, about 100 feet away from the existing lighthouse, across the gut or channel, and in a south-easterly direction. It has the advantage of partial protection, towards the west and south-west, by the House Rock and reef, but the disadvantage of being considerably lower in elevation. No portion of the site rises above the half-tide level, and the lowest parts, where the foundation courses of the new structure are to be laid, lie 4 feet below the low-water level of an ordinary spring tide; whereas the rock whereon Winstanley, Rudyerd and Smeaton carried on their operations, so far as relates to the immediate site of their labors, was entirely above the half-tide level, and its summit at the present landing-place is not covered at high water of ordinary spring tides. It will readily be understood that this constitutes a material aggravation of the difficulties and hazards, already great, of this new and arduous enterprise. For not only is the exposure to the action of surf and ground-swell more than proportionately increased, but the duration of the already too limited time within which it is possible to carry on work "in the dry" is most seriously shortened; and no inconsiderable portion of the basement must be executed entirely under water. The retention of the old tower during the construction of its successor is a *sine quâ non*. The lower level of the foundation for the new work has also exercised an influence on the form, proportions, and dimensions of Mr. J. N. Douglass's design, which is not only very much larger than that of Smeaton's, but varies considerably therefrom. Fundamentally the same general form is to be adopted; and, technically speaking, the shaft of the tower is a concave elliptic frustrum,—realised in Smeaton's original conception as the bole of an oak,—but, in order to give weight and solidity to the substructure, with corresponding power of resistance to the violence of the waters, the lower courses of masonry, up to and inclusive of the twelfth, are to be perfectly cylindrical in form up to the level of about 3 feet above the high-water level of ordinary spring tides. At this point there is a diminution of more than 8 feet in diameter, forming a commodious landing platform, whence springs the shaft proper of the tower. The diameter assigned to this cylindrical base is 44 feet, and that of the tower at its springing is between 35 feet and 36 feet, at a height of a little over 22 feet above the foundations. The circular shaft attains its smallest dimensions (18 feet 6 inches diameter) at a height of about 134 feet above the rocky bed of its foundation; swelling out, with a bold and graceful cavetto, to an enlarged diameter of 23 feet maintained up to the level of the gallery-course or lantern floor, at a total height of 142 feet above the base of the light-house, and 122 feet 6 inches above the level of high water of ordinary spring tides. The magnitude of this noble light-tower will be at once apparent by comparison with the similar dimensions of its existing predecessor. Smeaton's shaft diminishes from a diameter of 34 feet at the foundation-course to 26 feet at the level of high water ordinary spring tides; and thence to 20 feet at the entrance door, and 15 feet at the top, the gallery-course being but 61 feet above high-water mark, and the lantern-floor about 7 feet higher. Thus the new light will be displayed at an elevation 55 feet greater than that of the old one, and its range of visibility and efficiency will be proportionately extended. It would be superfluous, in regard to an as yet unexecuted work, to describe minutely all the proposed details of its construction; but some few of the general features of the design may be glanced at with interest. The structure is to be built entirely of granite, and to be entirely solid (except a small water-tank) up to the level of the entrance floor, at about 22 feet above the landing-platform; the access from low-water mark being by an outside step-ladder, formed of gun-metal cleats, recessed in the granite below the platform, and projecting from the surface of the tower above that level. The foundation is to be formed by cutting away the rock in benchings or steps, for the first four courses, all the stones which bed on the rock being secured thereto by metal bolts. Throughout the entire structure every individual stone will be closely united, or bonded in to those surrounding it, by solid dovetail projections, fitting into corresponding recesses; and each course of stones is similarly to be connected with those above and below it; so that in this manner, when set in Portland cement, the entire mass will require almost the homogeneity and strength of the solid granite rocks from which its component elements were quarried, as has been amply demonstrated by experience. The hollow upper portion of the tower will be similarly built, the rings being formed of single stones running through from the inside to the outside of the shaft. The internal diameter, as proposed, varies from 11 feet 6 inches to 14 feet, and the thickness of the ring from 8 feet 6 inches to 2 feet 3 inches. This part is to be divided by arched granite floors into nine stories, apportioned as stores, coal, oil, crane, living, bed, and service rooms. The door and window openings will be provided with gun metal doors, sashes, and shutters; and the general fittings of the tower are proposed to be of the same first-class, solid, and expensive character,—therein lying true economy, from the very situation, nature, and purpose of the lighthouse. Summing up the total quantity of the granite in the proposed new tower, it is approximately something less than 69,500 cubic feet, giving to the mass a total weight of about 5,150 tons of masonry. The metal-work in cast, malleable and wrought iron, in gun-metal, Muntz-metal bolts, copper, and brass and other materials will make up a gross total of about 50 tons more, or 5,200 tons

in the whole. This great mass will have to be wrought, set up, and fitted together on shore, taken down, loaded in vessels, transported by sea to the Eddystone rocks,—a distance of fourteen miles from Plymouth—and there unloaded, hoisted and built into position, at a mean height of 43 feet above the level of low water of an ordinary spring tide. The time allowed for the completion of the work is five years, giving an average of 1,030 tons to be erected in each year, practically limited to the summer season, so far, at least, as the actual work at the rock is concerned, inasmuch as during the winter half of the year it is impossible to carry on operations of this kind at all; and it may be added, indeed, that the work can only be executed intermittently even during the summer months.

ORDNANCE AND NAVAL.

THE GARRETT TORPEDO BOAT.—We are, this week, in a position to give details respecting the Garrett torpedo boat, the launch of which, at Birkenhead, on the 6th inst., was tersely announced in last week's *Iron*. She is a small but perfect specimen of the larger boat which would be required for some of the more difficult kinds of submarine work. It is cigar-shaped, and runs rather abruptly to sharp points at both ends, the total length from point to point being 14 feet and the width across the center 5 feet. It has been constructed of plates of iron 3-16th of an inch in thickness, riveted together, and weighs, inclusive of ballast, about 5 tons. To the outside a coat of lead-colored paint has been given, and this accomplishes the object aimed at in concealing almost all outlines except those which rise above the surface of the water. When floating at its normal or resting level, the position of the boat is revealed by a "conning tower," which rises for about 2 feet from the center of the cigar and forms a manhole, through which access is obtained into the interior. In the sides of the tower, which is of square shape, are round glass windows for outlook, and two brass caps, the uses of which will be explained hereafter. The balance of the boat is preserved, and the tower maintained in an upright position, by a leaden keel nearly 2 feet bread and about 2 tons in weight. An ordinary four-bladed screw-propeller revolves at one end of the boat mounted on a shaft, which communicates with the interior through a water-proof chamber. The steering power is obtained by means of rudders worked by suitable gear from within. These outward appliances and accessories, however, add little to the apparent bulk of the boat, most of them being almost invisible even when the craft is resting at the surface. Little unnecessary and unoccupied space is to be found within, although there is ample room for the movements of the operator. Upon the latter falls the task of propelling the boat through the water, and he causes the screw to revolve by means of an ingenious combination of treadle and fly-wheel. Of the more important features of the interior are some water-tanks located at each end of the boat, and a force pump, with powerful lever handle and tap, within easy reach of the manipulator. This is the actual machinery of descent as distinguished from that of propulsion. Once within and assurred that the manhole cover has been securely closed down upon him, the operator descends to the desired depth by turning the tap to his right. This admits into the tanks a quantity of water, which, overcoming the buoyancy of the boat, causes it to sink rapidly. The descending motion may be slackened, as it may be arrested, by the same method. But to cause the boat to ascend it becomes necessary to use the force pump. This appliance, by expelling the water from the tanks, restores the lost buoyancy, and the boat ascends with a rapidity exactly dependent upon the amount of force employed. It may sink to a depth of 30 feet, or may linger 6 feet below the surface, and it can be moved forward or backward at any desired distance from the surface. The details of the inventor's method of purifying the air within the boat, in order to make it supportable during a close confinement of perhaps several hours, are at present secret, and form, without doubt, a main feature of the scheme. In his descent the operator takes with him a number of iron tins of compressed air, a bottle of oxygen, and a number of tin cases containing a mixture of chemicals. A case is strapped to his back after the manner of a knapsack, and when seen at work through one of the windows, he is observed inhaling air, and as rapidly sending it through a tube which enters his mouth and passes over his head to the case on his back. The air passes through the chemicals, is purified, and again enters the lungs of the operator, to be again sent through the tube for purification. When a case is exhausted of its purifying properties another must be taken up and mounted. But these are not the only duties, apart from the mere working of his vessel, which fall to the lot of the submarine traveler. Oxygen must be added from time to time, and danger is sure to ensue if he forget the important rôle played in the safe navigation of the boat by the compressed air. He is careful to maintain as far as possible a mean between the outward pressure of the water, which increases with the depth, and the inward pressure of the air, which he is at pains to augment when necessary by opening one of his cases of air. In addition to this, he is supposed to keep a bright lookout for all objects lying in his way, or moving in his vicinity. If attacking a man-of-war lying at anchor, he descends to the necessary depth, moves cautiously forward, and when close to the mooring or other chain unscrews the two caps in front of his tower. This operation gives entrance to a quantity of water, but as the holes are merely flanked internally by a long flexible arm-sleeve of stout material closed at the inner end, no water actually enters the boat. Viewed from within, these sleeves would look like long pendent stockings hanging down inside full of water. The operator pushes his arm through them, turning them as it were inside out, as he pushes them through the holes into the water around his vessel. Using each as a sort of glove, he attaches a hook hanging outside his boat to the

chain of the man-of-war, puts on his caps, and moves his craft quickly to the rear. The motion draws taut a loop line, and runs a torpedo from his rear up to the chain, where it is exploded either by the shock of contact or by electricity. The weakest part of the hull of a large vessel might thus be sought out and attacked with tremendous effect.

When the boat is below the surface artificial light is of course necessary Mr. Garrett has discarded all methods capable of adding impurity to the atmosphere. He uses a lamp formed of two Gassiot (glass) tubes, partly exhausted of air. When a current of induced electricity is passed through these tubes a soft bluish light is the result, and there is sufficient illumination for all the necessary operations. The ordinary electric-light, of much brighter flame, would have to be employed for purposes of exploration or observation without, and the inventor has this extension of his scheme in contemplation. Electric communication between the boat and, say, a steam launch far in the rear, is provided by sending and return wires in one strand passing through a well-stopped hole in the tower, the telephone and an ordinary electric call-bell being sufficient for the purpose.

The experiments were, generally speaking, of a very successful character. Manipulated very cleverly by the inventor, the boat sank and rose to the surface, moved forward above, and was propelled below many times during the five hours occupied by the inspection. The strange appearance of the vessel was a matter of much remark. When floating with its tower just level with the surface of the water it resembled the snout of some marine monster, an impression which was strengthened when it blew up volumes of water after the manner of a whale. Mr. Garrett remained below on one occasion an hour and a-half without requiring any assistance, and so well had the purification of the air been accomplished that an improvement in the quality of the latter was noticed on the manhole being removed. Subsequently the inventor remained below a little over an hour, intending to illustrate his method of attaching the torpedo and of using his arms outside the boat. His inability to do so illustrates the precariousness of and danger of even the new method of submarine navigation. He had no sooner unscrewed the caps below, admitttng the water into the sleeves, than he discovered a leak in one of them, through which the water spirted, threatening momentarily to enlarge the hole, and fill the boat. He had presence of mind enough to seize and twist the arm, and while stopping the leak by this means, to work the force pump with the other hand, and thus raise himself to the surface. During the greater part of the time, during which the experiments lasted telephonic communication was maintained between the boat and the steam launch conveying the party.

The present speed of the Garrett torpedo boat is about 4 or 5 knots an hour. The specimen under notice, however, is designed for the use of one man. The inventor contemplates a boat of proportionately greater strength and size that may accommodate and be worked by three men. An improvement of the means of propulsion is also in view, the most suitable being gas or compressed air; this would increase the speed to a maximum of at least 10 knots, while increased speed would give increased command over the steering of the boat. The vessel used on this occasion was merely an experimental one, but quite strong enough to bear the pressure met with at a depth of 30 feet. A larger vessel would have more liberty in this respect, but as most of the purposes of such boats may be accomplished within a comparatively few feet of the surface, the capacity to descend to great distances is by no means absolutely necessary. Mr. Garrett has already been in communication with the Admiralty on the subject of his boat, and we understand that he is about to report the particulars of his invention to that board. He attaches primary importance to the chemical as compared with the mechanical part of his invention, for which he has already taken out a provisional patent.

The new boat, with all its machinery, was made by Messrs. Cochran and Co., engineers and ironfounders, Birkenhead, the work of construction occupying about two months.

BOOK NOTICES

SLIDE-VALVE GEARS. By HUGO BILGRAM, M.E. Philadelphia: Claxton, Remsen & Haffelfinger. Price $1.00. For sale by D. Van Nostrand.

This little book presents a new graphical method for analyzing the action of slide-valves designed to simplify the solution of all such problems. The illustrations are abundant, eighty in number, and are otherwise sufficient for the purpose.

The three parts to the work treat respectively of the Slide-Valve, Link Motions and Cut-Off Gearing.

Many students who fail in obtaining needed instruction from more elaborate treatises will doubtless find their wants abundantly satisfied by this compact little work.

MANUAL OF INTRODUCTORY CHEMICAL PRACTICE. By GEO. C. CALDWELL, S.B., Ph.D. and ABRAM A. BRENEMAN, S.B., of Cornell University. Second Edition revised. New York: D. Van Nostrand. Price $1.50.

This manual was originally designed as a guide for students beginning laboratory work. The result of two years' trial justifies a new edition of the work, and also the expectation that it will be acceptable to teachers who wish to illustrate a short course in chemistry.

The plan is chiefly to illustrate the character of chemical changes as the following extract from the contents will show: Introductory; Fusion-Vaporization; Solution Crystalization; Conditions affecting Reactions; Properties of the Elements; Compounds; Combining Proportions; Oxidation; Flame Reduction; Grouping of Elements; Binary and Ternary Compounds; Bethollet's Laws; Decomposition; Surface Action; Quantitative Analysis.

A complete list of apparatus needed is given, with copious illustrations. This is a book that has been long needed by teachers of Elementary Chemistry.

RAILROADS—THEIR ORIGIN AND PROBLEMS. By CHARLES FRANCIS ADAMS, Jr. New York: G. P. Putnam's Sons. Price $1.25. For sale by D. Van Nostrand.

These two essays will be widely read on both sides of the Atlantic. As Railroad Commissioner of Massachusetts, the writer has of late years given annually such evidence of his ability to deal with this great problem as to gain respectful attention to his views in many countries.

The second essay, the Railroad Problem, as it is presented to all countries is of the most general interest.

The masterly character of the author's previous writings in this field is evident in this essay.

CHEMICAL EXPERIMENTATION. By SAMUEL P. SADTLER, A.M., Ph.D. Louisville: John P. Morton & Co. Price $2.50. For sale by D. Van Nostrand.

This is an excellent guide to either laboratory or lecture-room work, and will prove serviceable for either teachers or pupils.

The series of suggested experiments includes all the non-metals and thirty of the metals. The illustrations are numerous and of the most excellent character. The directions for the preparation are exceptionally clear.

An appendix gives specific instructions about the common manipulations of the laboratory such as cutting and bending glass, blowing bulbs, fitting up corks, etc., etc.

Some useful tables, comparing the different scales, are also added.

ANNUAL REPORT OF THE CHIEF SIGNAL OFFICE TO THE SECRETARY OF WAR FOR 1877. Washington: Government Printing Office.

The present report is in no particular behind its predecessors. Some new features in charting observations are noticeable, and the general excellence of the maps is in every way gratifying.

There is an evident determination in the department to maintain the position now held—that of first in the world in all that pertains to observing phenomena, and freely disseminating such knowledge as is obtained from the information received.

Ninety-five stations make tri-daily telegraphic reports, thirty-two make one telegraphic daily report only, and one station only sends two reports; a total of 128 stations reporting by telegraph.

Some reduction of the force was made by Act of Congress, July, 1876, which it is hoped will be but temporary. A brief examination of the results of the last two or three years will lead to the conviction that true economy lies on the side of an extension of the system of observations under the superior management that now directs it.

A TREATISE ON FILES AND RASPS. By Nicholson File Company, Providence.

This is a beautifully illustrated thin quarto, treating briefly of the method of file manufacture and, with great fullness, of the varieties of files and rasps manufactured by this enterprising company.

VAN NOSTRAND'S SCIENCE SERIES, No. 38.

MAXIMUM STRESSES IN FRAMED BRIDGES. By Prof. WM. CAIN, A.M., C.E. New York: D. Van Nostrand. Price 50 cts.

This number discusses the Howe, Pratt, Triangular, Whipple, Fink, Bow String and Schwedler Bridges, for the maximum strains caused by two locomotives and a train of cars—the usual loads assumed in practice. A comparison is also made of the respective weights of these trusses as computed from the strains. The unit strains used in finding these weights are obtained from a modification of Launhardt's formula, which is based upon the well-known Wöhler's law.

The new features in this book are the analytical treatment of the subject of maximum chord strains due to the loads assumed, the ascertaining the most economical depth of trusses, besides other points.

The discussion of the Schwedler bridge—which is so earnestly recommended by its author—will probably be of interest to engineers who have not studied this system.

The treatise is complete in itself; the full analysis for each truss being given; and it is hoped that the compact form in which the subject matter is presented—stripped of unnecessary matter—may prove an agreeable feature to engineers.

MANUAL OF THE VERTEBRATES OF THE NORTHERN UNITED STATES. Second Edition. By DAVID STARR JORDAN, Ph.D. Chicago: Jansen, McClurg & Co. Price $2.50. For sale by D. Van Nostrand.

This is for the use of students of zoology to aid in identifying the species of the vertebrates of our own country.

The author has studied briefly and has got, we presume, a complete manual within a convenient-sized volume, useful to collectors all over the country.

THE LIFE OF JOHN FITCH. By THOMPSON WESTCOTT. Philadelphia: J. B. Lippincott & Co. Price $1.50. For sale by D. Van Nostrand.

A new edition of this biography of the inventor of the steamboat is noteworthy. It is in good style, and as it is a record of an important era in steam engineering in this country, it is worthy of a place in every library.

MANUAL FOR MEDICAL OFFICERS OF HEALTH. By EDWARD SMITH, M. D., F.R.S. Second edition. London: Knight & Co. Price $3.50. For sale by D. Van Nostrand.

The duty of the health officer in this country is in general not very well defined; the functions of such an officer are, as recent experiences have taught us, but illy understood. But, as in our present condition which promises improvement, we have followed the lead of older countries, it is reasonable to infer that from Dr. Smith's writings much may be gleaned which will prove valuable in the future.

Although written for use in England, a very considerable portion of the work will be found valuable here.

L'Annee Scientifique et Industrielle. Par Louis Figuier. Paris: Libraire Hachetti. Price $1.40. For sale by D. Van Nostrand.

This Scientific Annual chronicles the advance during 1877 in the several departments of Astronomy, Meteorology, Physics, Mechanics, Chemistry, Building Construction, Biology, Hygiene, Medicine and Industrial Arts.

The selection of articles and their arrangement for this Annual are good. The only illustrations are of the Bell Telephone.

Handbook of Inspectors of Nuisances. By Edward Smith, M. D., F.R.S. London: Knight & Co. Price $2.00. For sale by D. Van Nostrand.

This work is of more use in Great Britain than in this country, being adapted to the laws of that country. It is to be hoped, however, that it will serve as a guide in shaping our laws so as to insure a better condition of sanitary regulation in the future.

The methods of conducting examination of sewers and of disinfecting filthy localities are such as may be profitably followed in any civilized community.

Food from the Far West, or American Agriculture. By James Macdonald. New York: Orange, Judd & Co. Price $1.50. For sale by D. Van Nostrand.

This is made up from a series of letters to the *Scotsman*, which the author was commissioned to write to that paper, in order to inform its readers on the subject of the importation of dead meat from the Western States. Four chapters have been added to the above to complete the book. One of these presents statistics, two are devoted to American Short-Horn Breeding, and one is on what science says to the cattle feeder.

As a summary of the meat producing resources of our Great West, the work is doubtless accurate, and is certainly interesting.

Sanitary Engineering. A Guide to the Construction of Works of Sewerage and House Drainage. By Baldwin Latham, F.G.S., C.E. Second Edition. London: E. & F. N. Spon. Price $12.00. For sale by D. Van Nostrand.

The first edition of this book was speedily exhausted. The demand was still so great that an American reprint was issued in parts. It gave an impetus to Sanitary Engineering in this country which was much needed.

The second edition is much larger than the first, the additional matter relating chiefly to improved methods of Sewerage.

The work still holds the first place as a compendium of Sanitary Engineering practice.

Electric Lighting. A Practical Treatise. By Hippolyte Fontaine. Translated by Pajet Higgs, LL.D. London: E. & F. N. Spon. Price $3.00. For sale by D. Van Nostrand.

This work describes chiefly the Gramme Machine and the different forms of lighting apparatus which have been tried in connection with it.

The subject is one of great interest, as the time of lighting public squares, railroad stations, and public halls, by the electric light, seems certainly at hand, and, although we have not passed the experimental stage, the French engineers have accomplished so large a measure of success that we are at present content to accept the methods they recommend. The summary of their processes is presented by M. Fontaine.

Oeuvres Completes de Laplace. New Edition. To be completed in seven volumes 4to Paris: Gauthier-Villars. Price, per vol. $8.00. For sale by D. Van Nostrand.

The works of Laplace still hold their high position in the estimation of students of mathematical science. To read the Mecanique Celeste understandingly is to earn the respect of mathematicians; to omit such a labor in a course of mathematical study is to create the suspicion in the minds of scholars that the claims of such student to a fair order of mathematical talent are, at best, pretentious.

There seems to be now no promise of a time when these works will be held in less esteem. Although other processes of investigation may supersede those of Laplace, yet the accomplishments of this great astronomer are so identified with the material progress of science, that his name is as familiar as Newton's, and libraries in any country are incomplete without his writings.

Institution of Civil Engineers.—Through the kindness of Mr. James Forrest we have received the following publications of the Excerpt Minutes of the Proceedings of the Institution of Civil Engineers:

The Centrifugal Pump, by Wm. Cawthorne Unwin, M.I.C.E.

The Flow of Water through Level Canals, by James Atkinson Longridge, M.I.C.E.

On the Ventilation of the Mont Cenis Tunnel, by William Pole, F.R.SS.

The Strength of Flat Plates and Segmental Ends, by Daniel Kinnear Clark, M.I.C.E.

The Main Drainage of Paris, by Felix Target, A.I.C.E.

The Huelva Pier of the Rio Tinto Railway, by Thomas Gibson. A.I.C.E.

Chemical and Physical Analyses of Phosphorus Steel, by Alexander Lyman Holley, M.I.C.E.

Railway Appliances at the Philadelphia Exhibition, by Douglas Galton, F.R.S., A.I.C.E.

MISCELLANEOUS.

Rensselaer Polytechnic Institute.—The Alumni of this celebrated Institute, regardful as they have ever been of sustaining its fame, will be gratified to learn of the appointment of David M. Greene, C. E., as the Director.

Professor Greene graduated at the Institute with the class of 1851, and subsequently occupied the chair of Professor of Geodesy. He was for a time also the Professor of Engineering in the U. S. Naval Academy.

For the past few years he has been busily engaged with his professional labors. He has worn a high rank among American Engineers, and his recent appointment will be especially gratifying to his confreres of the American Society of Engineers.